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THE REPORT

OF

THE SOUTH SHIELDS COMMITTEE,

APPOINTED

TO INVESTIGATE THE CAUSES

OF

ACCIDENTS IN COAL MINES:

CONTAINING AN EXAMINATION OF—

SAFETY LAMPS;
VENTILATION;
SCIENTIFIC INSTRUMENTS;
INFANT LABOUR IN THE MINES;
PLANS AND SECTIONS;
SCIENTIFIC EDUCATION OF OFFICERS OF MINES;
GOVERNMENT INSPECTION; AND
MEDICAL TREATMENT AFTER EXPLOSION.

WITH PLANS AND APPENDIX.

LONDON:
PUBLISHED BY LONGMAN, BROWN, GREEN, AND LONGMANS.
GATESHEAD:
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REPORT.

Pit Coal, so necessary for the arts and prosperity of Britain, and from her climate essential to the comfort and enjoyment of her population, is produced by a severity of labour and risk of personal safety to the miner which the workman of no other occupation is exposed to.

A pitman's occupation.

The pitman descends 200, 300, and in some instances more than 500 yards[a] into the bowels of the earth, and there traverses subterranean passages, frequently from two to three miles in extent, to his work; where, by the glimmering of a small candle, or more imperfect lamp, in a space seldom six feet high, and oftener three and four, he labours in a stooping posture, sometimes lying on his side for eight or ten hours together in an impure atmosphere, to extract the mineral that above-ground is diffusing light, heat, riches, and enjoyment.

Its dangers.

In such a situation, often without a moment's warning, he is overtaken by destruction. The gases generated in such abundance in the mine, from some accident suddenly explode and fill the pit with death. In an instant, and in the most fearful manner, he is scorched and shrivelled to a blackened mass, or is literally shattered to pieces against the rugged sides of the mine; or, if out of the immediate range of this terrible piece of ordnance, in a few seconds the *after-damp* spreads itself in every direction, and poisons beyond recovery all that it may reach. Humanity has too frequently to deplore these fearful accidents. Within the last 20 years the coal district of the Tyne and Wear alone has had upwards of 680 miners so destroyed.

It is time that some comprehensive plan for their better security be adopted. The country cannot intend to abandon this useful class of men for ever to such a fate.

Importance of coal mines to Britain.

These mines so worked and so exposed are becoming daily more important to society in the advanced state of the arts. To Britain they are of more consequence than mines of gold and silver; they set her stupendous machinery in motion, raise her to a position the highest in the scale of nations, and bring her vast dependent territories, scattered over the globe, with all their valuable productions, within the easy access and jurisdiction of the parent state.

Their exhaustion, or the cheaper extraction of coal in another country, would bring with it serious injury, if not ruin: every principle of national superiority in her manufacturing and commercial greatness, of which they are the spring of action, would be lost.

Geological errors in calculating the supply of coal.

It is an erroneous basis of calculation to assume the entire geological coal disposable to the country. Under the present system, in her finest description of coal of the northern field, there is even, in the workable strata, a loss in its extraction of 36½ per cent., or more than one third; and in the thin seams, that will not repay the expense of working, at least 30 per cent. of the entire

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[a] Monkwearmouth pit, in the county of Durham, is 528 yards deep.

Extent of the coal fields of Britain.

stratified coal is left unattempted in the mine.[b] The views of theoretical geologists, without making waste, unworkable seams, and relative cost of extraction elements of their calculations, would tend, if acted on, to the most incorrect practical conclusions and national extravagance of the most disastrous kind. One geologist (Mr. Conybeare, Introd. Geol.) believes the Yorkshire and Derbyshire coal field to rival or surpass in importance that of the north, and which he conceives to be the re-emergence of the latter from beneath the magnesian limestone. Another (Lardner's Cyclopædia—Fossil Fuel,) makes the great northern coal field extend over 1,500 square miles, but omits to state that on an average, even in the most productive measures, not more than 29 feet of workable coal, by pits often 200 fathoms down, in which upwards of 36 per cent. of it is left behind, can be procured; that some of the most valuable seams crop out towards the magnesian limestone, and that a vast proportion of this geological coal field is removed by distance and other natural obstructions beyond the reach of remunerative employment of capital and labour. Other geologists (Philosop. Trans., vol. 96, and Bakewell's Geology,) make the South Welsh basin about 1,000 square miles of 95 feet of coal, containing 100,000 tons per acre, or 64,000,000 tons per square mile, or almost as much as will supply the country, at its present rate of consumption, for 3,000 years. Here again it has not been stated that there is nearly one-half waste, and that much of this Welsh coal is inferior anthracite, only applicable for certain purposes, or requiring a proportionate greater quantity for the same, although a portion of it is fine bituminous; and that the cost of production, of even the finest description, has hitherto prevented, to any extent, its meeting in successful competition, either in the home or foreign markets, the fine coal of the Tyne and other districts: that this infers general inferiority of quality and greater relative cost of working, which, should it become the sole source of supply, will make the coal of foreign countries to counteract its extent, and will leave Britain no longer a superiority on this point of great national importance. The same observations will apply to the less extensive and valuable coal fields of Scotland and Ireland.

The supposed time of their exhaustion.

On the other hand, Professor Sedgwicke is "convinced that with the present increased and increasing demand for coal, 400 years will leave little more than the name of our best seams;" and so thinks Professor Buckland. And thus ends the 1,700 or 2,000 years' supply assumed to exist on the Tyne and Wear. While Bakewell, in his Geology, observes—"We cannot but regard the exhaustion of our coal beds as involving the destruction of a great portion of our private comfort and national prosperity. Nor is the period very remote when the coal districts which at present supply the metropolis with fuel will cease to yield any more. The number and extent of the principal coal beds in Northumberland and Durham are known; and from these data it has been calculated that the coal in these counties will last 360 years. The only coal fields of any extent on the eastern side of England, between London and Durham, are those of Derbyshire and the West Riding of Yorkshire. The Derbyshire coal field is not of sufficient magnitude to supply, for any long period, more than is required for home consumption and that of the adjacent counties. There are very valuable beds of coal in the eastern parts of the West Riding of Yorkshire, which are yet unwrought, but the time is not very far distant when they must be put in requisition to supply the vast demand of that manufacturing county, which at present consumes nearly all the produce of its own coal mines. In the Midland Counties, Staffordshire possesses the nearest coal district to the metropolis of any great extent, but such is the immense daily consumption of coal in the iron furnaces and founderies, that it is generally believed this will be the first of our own coal fields that will be exhausted. The 30 feet bed of coal in the Dudley coal field is of limited extent, and in the present mode of working it more than two-thirds of the coal is wasted and left in the mine. If we look to Whitehaven, or Lancashire, or to any of the minor coal fields in the west of England, we can derive little hope of their being able to supply London and the southern counties with coal after the import fails from Northumberland and Durham. We may thus anticipate a period not very remote when all the English mines of coal and ironstone will be exhausted." The following detail will corroborate these views:—Of 45 feet of coal in a section of all the coal strata in one of the best pits on the Tyne, not 30 feet are workable coal. In the north, coal in the mine cannot be extracted to profit under 2 feet 8 inches, as in the *yard coal seam*; and in the western part of Wallsend the Bensham seam is considered unworkable at 2 feet 10 inches, although there are times when it is worked so low as at 20 inches.[c] But at Bingley, near Bolton, a seam 19 inches is wrought; near Manchester another seam of 15 inches; near Blackburn one of 13; and at Flockton, in Yorkshire, another of 16 inches. The thinnest seam wrought in Yorkshire is about 13 inches; in North Lancashire 20 inches; and at Shilbottle, in the Northumberland and Durham districts, 2 feet 6 inches; St. Lawrence, 2 feet 9 inches; Wylam, Walbottle, Charlaw, &c., it is 3 feet 2 inches. Most of the thin seams above specified as in operation, are chiefly wrought for local consumption, and cannot bear the expense of transit and competition for manufacturing and commercial purposes. The northern mines, it is thus seen, notwithstanding their facilities of market and carriage, prove geological coal lost for mining purposes under the present cost of working whenever the seam falls to 2 feet 8 or 2 feet 10 inches; and *coal even of a much greater thickness, unconnected with other seams, would not repay the cost of deep pits and expensive works*. Already the Tyne portion of the northern coal field, hitherto considered the most valuable, begins to experience the difficulties of exhaustion in the finer description of coal, and that of the Wear and the Tees, less worked than it, has the advantage in commercial competition of from 9 to 10 per cent. in price. For several years past in the London market, the Wear and Tees coal brings regularly a higher price by at least 2s. per ton, than that of the Tyne.

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[b] See Evidence before Parliamentary Committee of 1835. Buddle, 2,113, 2,118, and 2,156; Forrester, 2,631; and Smith, 3,153.

The thickness of the workable seams.

Competition of the coal of foreign countries.

When the expense of working British coal mines leaves no remuneration to the capital and labour employed, when brought into competition with the mines of other countries, then will they be as effectually lost to Britain, for purposes of ascendancy, and their produce as exports, as if no longer in physical existence; and her superiority in the mechanic arts and manufactures, *ceteris paribus*, it may well be feared, will be superseded. The more extensive and easily accessible coal fields, both bituminous and anthracite, of the United States of America, which are to the westward of the Alleghany mountains, 1,500 miles long and 600 broad; and the fine anthracite combined with bituminous coal of Pennsylvania, running on the east of these mountains as far as lake Ontario, afford supplies of the finest coal, that time would almost seem incapable of exhausting. They are at present only deterred from coming into competition by the want of abundant capital and cheap labour. But as that country increases her population, which she is doing at the rate of 33 per cent. every ten years, and their industry at the same time, *pari passu*, accumulating capital, it is to be feared that her mineral resources at no distant day may not continue the only exception to her natural produce unexported. They are already turning their attention to them, and the legislature of Pennsylvania in 1838 voted 18,000 acres to public companies for the purpose of working coal. This view is sustained by the landing (as at present) British coal at a less cost than the mineral can there be wrought upon the coal fields of Pennsylvania. It is not the want of coal, but of capital and of labour that allows the more cheaply wrought British mineral to seal up the American mines. *It is within the range of possibility to reverse it.*

The north part of France and Belgium are rich in fine coal; and the latter is geologically connected with Germany by a chain of carboniferous rocks. Saxony, Bohemia, and Silesia have also abundance of coal. In France, the department of Aveyron is said to be able, if properly developed, to supply all France. At St. Etienne, the heart of the French mining district, coal can be extracted as low as in Wales, and the expense of it throughout France is imputed to the absence of easy lines of carriage and communication, which enable English coal to be sold on the French coasts at a profit; but which again is met by the competition of the coal of Belgium, that even at Marseilles can appear in the same market with success. A prejudice in favour of wood fuel, and an insufficient national demand have prevented the French coal fields from developing their great resources. Russia, Syria, the East Indies, China, Australia, and many other parts of the world abound with this valuable mineral, and stand ready when favourable circumstances may present themselves, to reduce, at the least, this important source of our national wealth, and add to their power of production in the arts and manufactures.

---

[c] Parliamentary Evidence, 1835, 2,287.

Unceasing exertion, and the adoption of every scientific improvement adapted for the extraction and economising of her mineral wealth, can alone enable Britain to continue at the head of the competition of the world.

It is, then, important, not only for the sake of humanity, but for the continued prosperity of Britain, that the hope of the future be not sacrificed to the interest of the present, and that a SAFE, ECONOMICAL, AND WELL-ARRANGED SYSTEM of working those mines be established. Hitherto they have been left only to chance and the unassisted efforts of individuals.

Appointment of the South Shields Committee.

The Committee of South Shields for the Investigation of Accidents in Mines, responding to their public appointment in 1839, after one of those devastating explosions that place a whole district in mourning,[d] entered upon their important duties with a determination to leave no exertion unspared for the accomplishment of their objects, and have laboured therein industriously for the last three years, unaffected by any influence, save humanity and the interests of the country. In doing so, the Committee, at the same time, have been careful to keep in view the great individual interests involved, and to contemplate the suggestion of no system or arrangements by which to them, and so to the public, great increased expense without ultimate remuneration might be produced; thus avoiding any augmentation of the difficulty and cost, and perhaps eventual serious injury of that production which it is the interest of all to render cheap and more abundant.

In resisting many of the humane and philanthropic suggestions laid before them, the Committee have had no ordinary difficulty to contend with, from the warmth and enthusiastic feelings of their projectors, but which, in some instances, had it been possible to enforce, would have annihilated several of the most productive mines of Britain.

Deeply impressed with the important objects of their investigation, and the difficulties with which they are surrounded, the Committee have endeavoured, by visits and experiments in the mines, by an accumulation of data, by examination of good practical pitmen, by communication with some of the ablest viewers of the country, by correspondence with distinguished scientific men, by a comparison of the different systems of mining, and by investigation of the mining laws and regulations of foreign states, to come to a fair and just conclusion on the various points bearing on their mission, and now submit the following REPORT, dictated by a firm determination to support the truth, the interests of humanity and the country, as the result of their labours.

The great leading subjects of the Committee's inquiry and consideration, as applicable to the prevention or mitigation of accidents in mines, have been :—

SAFETY LAMPS,
VENTILATION,
SCIENTIFIC INSTRUMENTS,
INFANT LABOUR IN THE MINES,
PLANS AND SECTIONS,
SCIENTIFIC EDUCATION OF OFFICERS OF MINES,
GOVERNMENT INSPECTION,
AND
MEDICAL TREATMENT AFTER EXPLOSION.

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[d] That at St. Hilda Pit, near South Shields, on the 28th June, 1839, in which 52 lives were lost.

SAFETY LAMPS.

Fire-damp.

The great element of destruction to miners is the dreadful ***Fire-damp,*** (Light carburetted hydrogen gas,) which is evolved in the greatest profusion from every pore of the coal, as well as from the roof and thill of the mine.

Its immense abundance.

So abundant is it in some of the northern mines, that to procure a natural gas light, as this Committee has more than once observed, a small hole a few inches deep has only to be made in the coal, and a tube inserted, when the gas discharges through it so freely as to enable it to be lighted at its end.[e] In the shot-holes made for blasting the coal, it is very common also for the gas to ignite at their mouths.

At Wallsend colliery (C. pit,) *for many years* there has been an incessant discharge of gas, which burns at the pit mouth, with a bright light, that is visible for miles. It is conveyed in metal pipes from a single *goaf,*[f] or reservoir, of not more than five acres, into which it pours, 280 yards below the surface, and 2,000 from the shaft. Day and night it continues to discharge at the rate of 5 $\frac{1}{5}$th hogsheads per minute,[g] and six years ago was more than double that amount.[h]

On the 14th of January, 1841, the shaft brattice of St. Hilda pit, on the Tyne, was burnt, and the ventilation thereby destroyed; five days afterwards the underground workings of the mine, full 70 miles in gallery extent, were so filled with partially diluted gas, which ascended to the surface in such quantities, that around the pit mouth the fires had to be extinguished, and operations were obliged to be carried on in the shaft with safety lamps for precaution against the dormant earthquake below.

An accident from a sudden emission of gas having occurred on the 2nd February, 1841, at Jarrow colliery, part of the shaft brattice having been destroyed, and the ventilation injured, before it could be restored fully 20 miles of passages, of upwards of 70 feet average area, and more than 7,700,000 cubic feet, were in three days charged with this dreadful combustible.

At Earsdon pit, (Northumberland,) in the Bensham seam, 104 yards down, when the Committee visited it on the 6th April, 1840, a large staple (a pit within a mine,) was being sunk to the low-main. About 50 feet below, the surface of the water in this staple was agitated briskly, as if boiling, by the escape of gas; a light with great caution was lowered into it, when the whole surface became a sheet of flame of nearly 30 feet area. It continued to blaze brilliantly, catching the gas as it bubbled from below; now flickeringly, now again in a bright glare in the most extraordinary manner; it seemed inexhaustible, and was at length extinguished with some difficulty.

Condition in the coal.

This gas, by the observations of Mr. Witham and Mr. Hutton,[i] appears to be in a highly condensed, if not a liquid state,[k] and probably has been forming and accumulating since the earliest period of the coal depositions.

---

[e] See also Parliamentary Evidence in 1835; 2,094, 2,095.

[f] Goaf, part of the mine whence the coal has been removed, and into which the roof has fallen in immense masses, and the floor risen; the whole appearing a chaotic confusion of rocks.

[g] At this Committee's visit in October, 1839.

[h] Parliamentary Evidence, 2,030; and Coroner's inquest at Wallsend explosion, 1835.

[i] The Internal Structure of Fossil Vegetables, 8vo., by H. T. M. Witham, 1833; and a paper read to the Literary and Philosophical Society, Newcastle, by Mr. Hutton in 1833; also the following note to one of the Secretaries from Professor Hope, of Edinburgh :—

> "SIR,—After enjoying the fair prospect of safety to the coal miner by the beautiful discovery of Sir H. Davy, it is most painful to find that the safety lamp does not prove the safeguard which it promised, and was believed to be.
>
> "I regret extremely that I can not offer any suggestions upon the interesting subject of your enquiries. I have not seen the evidence taken by the Parliamentary Committee.
>
> "*With regard to the source of the destructive gas, I incline to the opinion that it is coeval with the formation of the coal itself, and that it exists in a solidified state, ready to assume the æriform condition from some change of pressure, temperature, or other unknown cause.*
>
> "I sincerely wish that the investigation of the Committee may be attended with the happy results of contributing to the preservation of many valuable lives.
>
> "I am, Sir, your very obedient servant,
> (Signed) "THOS. CHAS. HOPE.
>
> "Dunglass, 6th August, 1839."

[k] Parliamentary Committee, Dr. Pereira, 3,982.

Though from its light specific gravity, this gas escapes into the atmosphere whenever exposed, yet the coal still retains a large portion of it: a piece of coal in a pail of water will emit it in abundance,[l] and instances are on record in which ships laden with coal have been nearly destroyed by its disengagement and explosion. On August the 5th, 1816, the ship *Flora,* of London, having just taken a cargo of coals on board in Sunderland harbour, blew up with a terrible explosion; the deck beams were broken, and the decks torn up.[m] On July 4th, 1817, the *Fly,* of Ely, lying at Brandling staith, on the Tyne, with a cargo of coals, just taken in, the gas from it exploded, burnt the captain in the cabin, tore up part of the deck, threw a boat from the hatches, and did other serious damage. Upon the 21st July, 1839, the sloop *Enterprize,* when at sea, with coals from Pembroke to Newport, Isle of Wight, had an alarming explosion, which fortunately only frightened, but did not injure the crew And the schooner *Mermaid,* of Guernsey, upon the 29th August, this year (1842), lying at South Shields, sustained an explosion: she had been laden that day with Hilda coals, and the hatches immediately battened down; when six hours after the gas from the coal exploded at the forecastle lamp, one man was knocked down and much burnt in the face, another injured, the mate struck down in the cabin, and a hatch started. A circumstance not undeserving of notice, lightning, in great abundance, was playing in the atmosphere all around the vessel at the time.

Explosions of gas from coal on board of ship.

The Fire Damp so abundant in coal appears only to require the removal of pressure or high temperature to disengage it; hence whenever the pressure of the impervious superincumbent strata is removed by the sinking of a pit, the gas pours out in the profusion stated, varying according to the condition of the atmosphere. At such time, if mixed with a certain proportion of atmospheric air, from 83 to 94 per cent.,[n] which is supplied by the ventilation of the mine, and brought into contact with flame or heated metal, it explodes with a force exceeding that of gunpowder. In mine explosions of this gas, men have been projected from the shaft like balls from a cannon; heads, legs, and arms have been found at a great distance from the pit mouth. In the Killingworth explosion in 1806, so graphically described by the distinguished engineer, Stephenson, who was present:[o] he saw "the discharge come out of the pit mouth like the discharge of a cannon—there was wood came up, stones came up, and trusses of hay, that went into the air like balloons; the ground all round the top of the pit was in a trembling state." And Mr. Buddle, in his able evidence at the coroner's inquest on the explosion at Wallsend, in 1835, declared that had the fire gone a little further it would have reached the magazine of about five acres of this gas, and its effects would have been that of an earthquake, and the village of Wallsend on the surface, with 280 yards of the structure of the solid earth between them, might have been destroyed. He states, that in another explosion at the Row Pit, Harraton, at which he was present, that men were propelled from the mine up the shaft 160 yards deep. "Every thing (he says) was blown away from its mouth." Near it "there was a body cut in two, the trunk and arms without the head were lying in one place, and the legs and thighs lying at four or five yards from it. At about 12 yards from the pit, there was a body lying without the head."[p] A boy, who had hold of his father's hand at the bottom of the pit, while the father stood accidentally within a niche, was blown up the shaft torn, and mangled, while the father escaped. It was this little boy's first day in the pit, and he had just come to his father probably to talk of the strangeness and the many anxieties of his novel situation.

Tremendous force of explosions.

Effects within a mine.

The following brief sketch of the scene *within the mine,* produced by an explosion of pit gas, was made by one of the Secretaries of this Committee on descending the St. Hilda pit immediately after the dreadful accident in June, 1839. In nearly the same terms it was written at the time, and appeared in the journals of the day:—"The deadly gas, the resulting product, became stronger and stronger as we approached. We encountered in one place the bodies of five men who had died from the effects of the gas, and had apparently died placidly, without one muscle of the face distorted. Then there were three more that had been destroyed by the explosion; clothes burnt and torn, the hair singed off, the skin and flesh torn away in several places, with an expression as if the spirit had passed away in agony. Going with a single guide, we encountered two men, one with a light, the other bearing something on his shoulders; it was a blackened mass, a poor dead burnt boy he was taking out. A little further on we found waggons that had been loaded, overturned bottom upwards, scattered in different directions; a horse lying dead, directly in the passage, with his head turned over his shoulder, as if, in falling, he had made a last effort to escape; he was swollen in an extraordinary manner.

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[l] Davy's Researches on Flame, pp. 21 and 22.
[m] Sykes's Local Records.
[n] Davy's Researches on Flame, p. 10.
[o] Parliamentary Evidence, 1,514.
[p] Parliamentary Evidence, 2,955 and 2,957.

"At one point in another passage, we suddenly came amongst 12 or 15 men, who, striving to reach the places where bodies or survivors might be found, had been driven back by the surcharged atmosphere of this vast common grave; their lamps were burning dim and sickly, with a dying red light, glimmering as if through a fog.

"All were feeling the effects of the poison. One poor man especially was sick and ill, who had been brought out in a fainting condition, and after having given him something to assist his recovery, he seemed still much affected. He was again asked where he felt most oppressed, he answered in a broken voice of suppressed agony, "*I am not well, Sir, I have two sons in there.*" The men who were exerting themselves for the recovery of their unfortunate friends, acted with a solemn, high-wrought, steady courage, without bustle, scarcely with a remark, and what remarks were made, were such as were necessary, brief, and decided, and generally in a subdued tone, such as human nature assumes in its most vigorous, perfect, and ennobling moments. We beheld there the deepest sympathies of the heart combined with a courage that had never been surpassed. Their companions were brought out insensible from the overcharged atmosphere, struck down at their feet almost without life, yet it produced no fear, no flinching, no hesitation, but they stepped gallantly forward to the same spot, with an almost certainty of suffering a like attack; and when returning to complete consciousness, with an absence of self and personal consideration above all praise, the first wish frequently expressed was to return to their dangerous duty."

Light carburetted hydrogen gas.

This deadly gas is the *light carburetted hydrogen* of Davy, Henry, Thomson, Faraday, and the British chemists, which the miners are always more or less amongst, and to whose terrible effects they are hourly exposed. Flame of a lamp or candle, a vivid spark, heated metal, or electricity, will produce its ignition.[q] Its weight (specific gravity, 0.5382,) being about half that of common air, it is found floating in the upper part of passages, goaves, and galleries of mines.

But there are other gases in the mines, one of which of much importance had never been observed by those distinguished chemists, though suspected by Sir H. Davy to exist in fire damp.[r] *Olefiant gas*, (sp. gr. 0.9722).

Olefiant gas.

The scientific Dr. Clanny also states in his Parliamentary Evidence, 353:— "He was of opinion that in some of our mines we have heavy or *carb. hyd. gas*, or *olefiant gas*, as it is generally called." It was, however, reserved for Professor Bischof, of Bonn, in his acute and ingenious analysis of the gases of the German mines to detect this combination of hydrogen; in one instance more than 16 per cent. of olefiant gas (hydrogene bicarboné) having been discovered to form the gas of a particular blower in one of the mines.[s]

"Il s'agit (he says) maintenant de decider la question, si les gaz des mines

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[q] Davy's Researches on Flame, p. 25.

[r] Ditto, pp. 10, 11, and 14.

[s] The following is his analysis of this gas:—

Hydrogène protocarboné,	0.7910
Hydrogène bicarboné,	0.1611
Gas étranger,	0.0479

Memoire sur l'Aerage des Mines, par M. Gustave Bischof, Professeur; ch. 11, pp. 254 and 5. See also ch. 1, p. 218, ch. 11, p. 261, of this work in the Report published by the Academy of Sciences, Brussels, in 1840.

d'Angleterre, analysés par les chimistes nommés plus haut, ne contiennent point d'hydrogène bicarboné, ou si ce dernier leur a échappé. Sans vouloir révoquer en doute le moins dü monde l'exactitude de ces chimistes, je dois cepandant rappeler que, depuis 25 ans, époque à laquelle ces analyses ont été faites, la chimie analytique, surtout l'analyse des substances gazeuses, a fait de grands progrés.

"M. Davy dit: le gaz des mines n'agit pas sur le chlore à froid; mais il nedit pas si, dans le volume, il n'a pas observé d'absorption. Puis il dit: une mesure du gaz des mines exige, pour être brûleé par l'etincelle électrique, *environ* deux mesures d'oxygène; il résulte de cette combustion *a peuprès* une mesure d'acide carbonique. On voit par là que ni la quantité d'oxygène qui a été consommée, ni celle de l'acide carbonique qui s'est produite, n'ont été determinées avec précision. Il se peut donc aisement qu'il y ait eu une consommation d'oxygène dépassaut le volume double, et une production d'acide carbonique plus grande que le volume égal; que, par suite, *le gaz des mines analysè par Davy ait conteuu un peu d'hydrogène bicarbonè.*

"Dans mes analyses, il s'est présenté une circonstance particulière que je tâcherai d'eclaircir par des expériences ultérieures, plutôt dans l'intérêt theorique que pratique.

"Si j'evaluais l'hydrogène bicarbonè au moyen de l'absorption par la detonation et de la quantité de l'acide carbonique qui s'etait formée, j'en trouvais tonjours une quantité plus grande que celle qui était fournie par la determination directe au moyen du chlore. Le calcul etait basé sur la supposition connue que la gaz hydrogène protocarboné consomme, par la detonation, son volume double d'oxygène, et produit un volume egal d'acide carbonique. La quantité plus grande d'oxygène qui fut consommée, et la quantité plus grande d'acide carbonique qui fut formée, durent nécessairement provenir d'hydrogène bicarboné, puisque ce gaz est le seul de tous les gaz inflammables qui, par sa detonation, consomme une plus grande quantité d'oxygène et fournisse plus d'acide carbonique que la gaz hydrogène protocarboné."

These experiments and arguments of Bischof seem clearly to show that the English mines contain this combination of hydrogen; and indeed, *a priori*, the nature and disposition of the two elements would indicate its probable existence.

The existence of this gas in the mine, now almost indubitable, is most important in the use of the safety lamps, as it explodes at a lower temperature than the light carburetted hydrogen: iron heated to redness will ignite it, the flame of which will again explode the fire damp.[t] The olefiant gas being nearly the weight of atmospheric air, will be found, when in motion, intermixed with it, but in the stagnant part of mines will probably take its place for a time in their upper regions, below the light carburetted hydrogen.

Sulphuretted hydrogen gas.

Another destructive and inflammable gas—*sulphuretted hydrogen*, (sp. gr. 1.1805)—appears also in the mines,[u] to add to the danger and death in which they are shrouded. The iron pyrites, it is probable, affords the sulphuretted hydrogen in large quantities in mines. This pyrites is so plentiful in the coal of the Tyne as to enable the skilful manufacturers of alkali in that district to extract sufficient sulphur from it (45 to 50 per cent.)[v] as a substitute for that of Sicily, and which, on being exposed to air and moisture, spontaneously ignites the masses of small coal and refuse at the pit mouths. In experiments by this Committee, moistened pyrites, in the ordinary temperature of the atmosphere, was found to give off the sulphuretted hydrogen freely and in abundance, and of course, in a wet mine, at a temperature from 65 to 75°, it will evolve it more rapidly. This gas, in addition to causing instantaneous death by inhalation, takes fire at the least visible heat of iron, and therefore at a red-hot safety lamp would at once explode a whole mine. It has been supposed to have been observed in the mine accompanied by gaseous oxyde of carbon, but which has not been found by Bischof in his careful and critical examination.

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[t] Davy's Researches on Flame, p. 25.

[u] Parliamentary Evidence, 876 and 1,853.

[v] One manufacturer states to the Committee that he gets some which regularly contains 50 per cent. of sulphur and 43 per cent. of iron.

Carbonic acid gas.

There is another gas, the produce of an explosion; often also in large quantities in old workings; and sometimes in such profusion in the Lancashire mines "that thousands of yards of space are filled with it in a single hour:"[w] the *carbonic acid gas*, the *stythe* and *choke damp* of the north, and the *black damp* of Lancashire.[x] A single breath of which pure is almost instant death; it is generally indicated to miners by a dim blueness and then an extinction of their lights; warning them to an immediate retreat. From its sp. gr. 1.5277 it will be generally found in the low parts and on the floors of mines, as the fire damp is commonly in the higher regions.

These are the dangerous and noxious exhalations of mines that are ever presenting themselves, to the injury or destruction of miners and the frequent interruption of their operations. The first of which, the fearful *fire-damp* would form the chief proportion of the atmosphere of mines, as in the goaves, but for the artificial introduction of atmospheric air in a ventilating current, that sweeps away in its course the gas as it presents itself in the passages. Notwithstanding which it finds recesses and imperfectly ventilated districts and there accumulates, and then explodes, as we have seen, so fearfully,—the terror of miners from the earliest working of the mines, and which for the last 50 years has employed the ingenuity and science of humane men to obviate its effects.

The Steel Mill.

Mr. Spedding early in the last century was stated to have invented the Steel Mill, by which the dangerous parts of mines were believed to be safely lighted by the sparks from it and flint, but which nevertheless sometimes exploded them, and brought on the danger it was intended to obviate.[x] Sometimes 100 of these dangerous instruments were in daily use in an inflammable mine.[y]

Humboldt's lamp.

Humboldt, so early as 1796, contrived a lamp that would burn in a foul atmosphere: it was isolated not only from the explosive gas, but also from the atmospheric air, and would consequently only burn while the air contained in it was unconsumed, which, of necessity, being of small quantity, rendered it entirely inoperative.

Dr. Clanny's first lamp.

Dr. Clanny, in this country, appears to have been the first man of science that conceived it possible to enter into a contest with this destructive element, and, sustained by his unwearied philanthropy, has never ceased, for 30 years, to devote his talents and exertions to mitigate the horrors consequent upon its explosions. A life so spent, it is to be hoped, will not be allowed to pass without some mark of respect from his country, or of gratitude from those he has laboured so much to benefit.

In 1813, Dr. Clanny invented a lamp that burnt safely in a fiery atmosphere, which, like Humboldt's, was also isolated, but was supplied with fresh air, as well as had that which was de-oxygenated withdrawn by tubes through water. Its inconvenience was the chief obstacle to its regular employment. From this time the idea of a safety lamp seems to have daily gained more strength in the mining districts.

Sir Humphrey Davy's visit to the north.

Sir Humphrey Davy having come down to the north on a visit to the coal mines by invitation of the Rev. Dr. Gray, a member of the meritorious Society at Sunderland for the Prevention of Accidents in Mines, saw and experimented on Dr. Clanny's Lamp, at the Rector of Bishopwearmouth's, in Sept., 1815;[z] and, after a visit to Wallsend colliery, with Mr. Buddle, he returned to London. About the same period, *Mr. George Stephenson*, by a series of

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[w] Parliamentary Evidence, 3,376.

[x] So late as Oct. 5, 1825, an explosion took place at the spark of a steel mill in the Hebburn pit, by which four men were suffocated by the after-damp; and on Nov. 27, 1830, two men met their death from the same cause in the same place.

[y] At Hebburn Colliery before the discovery of the safety lamp.

[z] Parliamentary Evidence, 336 and 285.

Mr. Stephenson's first experiments and lamp.

ingenious mechanical experiments at Killingworth colliery, had invented a *safety lamp;* and on the 21st Oct., 1815, it was satisfactorily proved. The principle of this lamp seems to have been that which has been since ingeniously adopted in that of Upton and Roberts; destroying the explosive nature of the inflammable air by consuming it before it passed from the lamp, which, in the original one of Stephenson's, was effected by a chimney, with a tube at the bottom for the admission of the air.[a] About the 4th Nov. of the same year, he substituted perforated metal plates for the same purpose, and it was then publicly tried at the Newcastle Philosophical Society.

Davy's invention.

While this was passing in the north, exactly at the same juncture Sir H. Davy in London, by a series of splendid scientific experiments had arrived at the conclusion that minute metallic apertures were impermeable to flame, and he superadded the discovery that fine wire gauze was the best mode of their application, and the surest prison for the flame in an explosive atmosphere.[b] In about three weeks from his visit to Wallsend, Mr. Buddle received from him two safety lamps, with wire gauze cylinders, on this principle.[c]

Since which time the *Davy Lamp,* as it is called, having been generally employed in inflammable mines in Britain and abroad with a perfect confidence in its powers, as a security against explosions, it becomes an important practical question to investigate its absolute or comparative safety.

THE DAVY LAMP.

The lamps of Sir Humphrey Davy which he adopted were formed of wire gauze, $\frac{1}{40}$th to $\frac{1}{60}$th of an inch in diameter; 28 wires or 784 apertures to the square inch, with a cylinder about 6 inches high and $1\frac{4}{10}$th in. diameter.

Sir H. Davy, in Sept. 1816, at one of Lord Durham's mines, fixed a brass pipe half-inch in diameter, at the mouth of a walled-off blower, which, when lighted, threw its flame the length of 5 feet; at this blower his single gauze lamp, when the iron wire began to burn with sparks, passed the flame, and ignited the external gas.[d] Sir Humphrey states in page 102 of his work on flame, "*where an explosive mixture is in rapid motion, it produces, as has been stated in page 77, much more heat, and in this case the radiating or cooling surfaces of the lamp must be increased or the circulation of air diminished:*" and to prevent its effects, he recommends in the same page "*twilled gauze, or a double or triple fold of wire gauze on one side of the lamp, or a screen of metal opposite to the direction of the current or a semicylinder of glass or of mica within.*" In appendix No. 4, in reference to the same effect, he says, "I should strongly recommend double lamps, in cases where miners are obliged to work for any time in explosive mixtures, or wherever currents are expected, or lamps with mica, or tin plates *within* the wire gauze, to prevent too great a circulation of air.—See page 103." But this refers to the production of intense heat when the "iron wire begins to burn with sparks." He goes on in the appendix, "but it is much better, in all cases of danger, to use *lamps which under no circumstances can explode;* such as those described in page 77." This still refers to the increase of heat, as will be seen in page 77, thus: "The same mesh which arrests the flames of explosive mixtures at rest, will suffer them to pass when in rapid motion; but by *increasing* the *cooling surface, by diminishing the size or increasing the depth of the aperture, all flame, however rapid their motion, may be arrested.*" This is the safety lamp: a wire gauze, with diminished apertures, that he states "*under no circumstances can explode,* owing to its "increased cooling surface." Yet Sir Humphrey adopts a lamp of 784 apertures to the square inch, though *we shall afterwards find one of* 1,024—*a much more perfect gauze—to pass the flame with the greatest facility.*

His mode of increasing its safety.

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[a] Parliamentary Evidence, 1,537.

[b] Researches on Flame, p.p. 18 and 40.

[c] Parliamentary Evidence, Buddle, 2,226; and Philosophical Transactions of Royal Society for 1816, in a paper read by Sir Humphrey Davy, November 9, 1815.

[d] Davy's Researches on Flame, collected works, Vol. VI., p. 103.

A shield, and a dangerous contingency.

The indefinite mode, as quoted above, of expressing the ***absolute necessity of a shield*** for the Davy lamp, in an explosive atmosphere in motion, seemed never to have been understood, and created some surprise 20 years after, when it was stated to be almost a principle of the lamp. Sir Humphrey Davy evidently, in his recommendation, means it merely as a precaution, as has been shewn, not to the passing of the flame in a cool lamp, but to the heating of the gauze and ignition of the gas from the incapacity of the burning metal to restrain the flame in that condition. Now Mr. Buddle, in his Parliamentary evidence (2,226), states, that Sir Humphrey Davy, on sending his lamp, warned him "that there was no hazard except in exposing it to ***a strong current, by which the explosion would be passed through the gauze cylinder.***" On his visit some time afterwards to Wallsend, Mr. Buddle further states (2,227) :—"But he pointed out a remedy at the same time for that contingency, and which we have always used; namely, by a tin screen which slides upon the frame wires of the lamp and encircles the circumference of the gauze cylinder to an extent of about $\frac{1}{2}$ to $\frac{2}{3}$rds of its circumference."

It is surprising that if Sir H. Davy was aware of this fearful contingency of the passage of the flame in a strong current, when the lamp was *not* heated to redness so as "to burn with sparks," which may well admit of doubt, that in his work on the Safety lamp, published for "practical purposes,"[e] he should not have especially pointed this out, and warned miners of its possibility and its remedy; and not have confined himself to a private notification of it to an individual, however distinguished, or a private party of which he was one, who, after 20 years' employment of the lamp, accidentally, in a Parliamentary inquiry announces, for the first time, this danger and precaution to the world.

It produced a strong sensation even amongst scientific miners; and Mr. Smith, who had been extensively employed as a mining engineer in England, Portugal, and British America, in his valuable evidence before the same committee thus expresses himself:—"Here I must remark, that I never heard, until I came into this room, that Sir Humphrey Davy had declared or made it known that with his lamp the miner was liable to explosion under particular circumstances. I have been very much amongst mines, and I never heard it until Mr. Buddle stated it in this room."

Discovery of the dangerous nature of the lamp.

Scientific men and lecturers, as *Pereira, Gurney, Birkbeck, Hemming,* and *Turner;*[f] had some time previous to this discovered and were beginning publicly to elucidate the important fact of this dangerous imperfection of the Davy lamp.

Here then is an admitted danger which Mr. Buddle—the anxious practical defender of his friend Davy's invention—(2,227), conceives to arise in explosive mixtures as in gas-pipe drifts "when the current is moving with a velocity of from 3 to 4 feet per second."

Now the average rate of the current through the mines, according to Mr. Wood (P. E. 901 and 908), and Mr. Buddle (2,314), is about 3 feet per second, which, especially should the miner be walking against the current at the same rate (*two miles an hour*) with his lighted lamp in hand, hurrying to or from his work through an explosive mixture in a gas drift, or any other passage of the mine, will originate this contingency, and bring on the risk of passing the flame through the gauze. Thus, it will be seen, that *the ordinary motion of the miner, with his lamp,* through a stagnant part of the mine, *will,* without any motion of the air, *produce of itself the danger that is now undeniable.*

This, then, is an acknowledged risk in the employment of the Davy lamp in the ordinary state of the mines, to be carefully and continually guarded

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[e] See note to his Collected Works, Vol. VI., p. 3.

[f] Parliamentary Evidence, Smith, 3,828. See also Upton's, 3,986; Mitcheson's, 2,562; Ryan's, 2,940; Embleton's, 4,070; Pereira, 3,960; Birkbeck, 3,884; Hemming, 1,926; and Turner, 1,927.

Few shields used in the northern mines.

against; and yet even in Wallsend Colliery, under Mr. Buddle's own able jurisdiction, the precaution of a tin shield, as was observed at the visit of this Committee on the 7th October, 1839, four years after his public declaration of such a danger, was very partially employed, the men generally working with the naked Davy lamp; and almost every other pit which the Committee have visited being precisely, as refers to this point of the lamp, in a similar condition.

This cause of the production of danger is further supported by experiments demonstrated and detailed, and facts related, a portion of which the Committee will take leave to adduce, as it is a matter of much practical consequence.

Experiments of Gurney.

The ingenious inventor of the Bude Light asserts:—"The results of those experiments proved that if an explosive mixture,, such as is found in coal mines, was made to pass at the rate of about 300 feet a minute—not 3½ miles an hour—through the meshes, that the flame would pass the gauze and inflame an explosive mixture on the opposite side."[g]

George Stephenson, Esq., imagines that some of the accidents, in which none are left to give account, may likely have occurred from the fall of the coal in working; for "when the coal comes down there is an immense gush of wind," he conceives, "sufficient to drive the flame through the gauze and fire the external atmosphere."[h]

Murray.

J. Murray, Esq., lecturer on chemistry, asserts:—"I have no doubt that many accidents have occurred with Sir Humphrey Davy's lamp—that lamp not being absolutely safe—igniting an explosive atmosphere." He thinks, in his experiments, when he passed the flame through the Davy lamp, that the velocity of the explosive mixture was "less than 300 feet per minute."[i]

Birkbeck.

Dr. Birkbeck states:—Sir Humphrey Davy's lamp "protects against ignition when the explosive gas is quiescent, but it is totally defective when that gas is in motion and can reach the wire gauze in that state of condensation which a moving column of gas always acquires; it then becomes no longer a safety lamp. In the usual mining operations, in bringing down two or more cubic yards of coal at one fall, he conceives that by the compression effected by it there will exist the same "facility of ignition that the motion of air in a current produces."[j]

Pereira.

Dr. Pereira, experimenting before the Parliamentary Committee with a lamp of meshes of 1,024 apertures to the square inch, *which is finer than any lamp ever used in mines*, passed the flame several times through the gauze of this Davy lamp; he also forced it through with an explosive mixture of street gas and air;[k] and then by exposing a red-hot Davy to a jet of coal gas, it was instantly ignited.[l] He adds (4,202):—"I presume, therefore, if I can cause the flame to pass through the wire gauze cylinder by means of a small jet of gas like this, that the passage of the flame will take place more readily in coal mines. If the miner move his lamp the danger is increased."

This motion, at such a time, may almost to a certainty be calculated to occur. The miner engaged at his work in a fiery mine, or in a fiery district of a mine, has not his lamp before him; but turning, perhaps accidentally, or from some flickering or increased glare reflected on his work, he sees his lamp on fire, perhaps in the upper part of the cylinder red hot,—he immediately seizes it and instinctively hurries from the spot, *giving rise to the motion and coincidences that are known certainly to produce explosion.*

The following observations of the Belgic Commission bear out this opinion:—"Considerant d' ailleurs que, méme dans le gaz éclairant l' action d' un courant d'air rapide peut enlever á cette lampe (the Davy) tous ces avantages, considerant que se courant peut etre le resultat, soit de la negligence avec laquelle on transporte habituellement les lampes, soit de la frayeur qui porterait un ouvrier á se soustraire ou danger par un fuit précipitée, en soufflant sur sa lampe pour l' eteindre, ou en la jetant loin de lui, soit par une parturbation accidentelle dans l' aerage, ou par toute autre cause; * * * * pour signaler cet appareil comme laissant encore beaucoup a desirer."[m]

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[g] Parliamentary Evidence, 9.
[h] Parliamentary Evidence, 2,941—2,943.
[i] Idem., 3,217—3,218.
[j] Idem., 3,883—3,889.
[k] Idem., 4,197—4,198.
[l] Idem., 4,200.

Explosions of the Davy lamp in the mine.

There are facts of absolute explosion from the Davy lamp in the mine that corroborate these experiments and this reasoning.

Mr. Mitcheson, mine agent in the Staffordshire Potteries, relates a case of the lamp passing the flame in Greendock Pit, and killing a man, at which he was present.

Greendock Pit explosion.

The pit was 314 yards deep; it had been standing for a while. The agent and two men went down with a Davy lamp. He afterwards came up, leaving the men to work. "When he came up (says Mr. Mitcheson) a ringe of water was thrown down, with the idea of increasing the ventilation of the pit, which it would do ultimately. As soon as ever that water was thrown down the pit fired: evidently proving that the water, making such a great pressure in the downcast shaft, caused such *an intense current of foul air into the lamp that the flame passed through and so fired all the sulphur.*" One surviving man, who was sadly burnt, said, "*that as soon as ever the great wind came* (which was, in fact, sulphur to them, they were at the bottom of the upcast shaft) *the gas exploded immediately.*"[n]

The flame passed in a current.

William Forrester, Esq., an extensive viewer in Staffordshire, stated:— "I have seen a lamp fire the carburetted hydrogen gas in a current of air in a thirling." The current was of considerable velocity: "it would blow a candle out;" and *when this current struck the lamp it ignited at the gauze and flew away with the air, and went out*;—it seemed to fly close from the gauze.[o]

Salton Low Bottom Pit.

In a Cumberland mine, *Salton-Low Bottom*, a father and son lost their lives by an explosion through the Davy lamp. In this pit it is the habit to agitate the air briskly when there is much gas, and so to sweep or brush the place, which is done with their coats. Every precaution, says the relater, "was taken by the father and son: they went into the workings in the dark, placed their two lamps in the air-course, and when they agitated the inflammable air it mixed with the atmosphere and fired the lamps, and the lamps exploded, and the fire traced up where the father and son were—they were both burnt to death." Subsequently to the accident "*the lamps were carefully examined, and all the lamp tops were found to be screwed on, so that it appeared that every precaution had been taken.*[p]

Certificate of the Davy lamp passing the flame.

Mr. Roberts, in his evidence, relates (3.484, 5, and 6) that three men were killed by explosion in a mine, in the gateway returning to the shaft, and their Davy lamps were found perfect and uninjured. And the same gentleman presented a certificate to the Committee of the House of Commons, signed by 18 persons of the Staffordshire mines, stating, on the inflammable air being brought to act on the Davy lamp they witnessed, "*that the flame passed through the wire gauze and ignited the gas outside.*[q]

William Pit.

At an explosion in the William Pit, Cumberland, thirty-three human beings, all that were in the pit, were destroyed, though working under the protection of the Davy lamp. "*They all had safety lamps.*"[r] No evidence was produced to show that the Davy lamp had not, in that instance, passed the flame or ignited the gas from a heated gauze.

Wallsend Pit, 1835.

The explosion at WALLSEND PIT in June, 1835, which killed 102 people at a blow, occurred in the employment of the Davy lamp: and *no investigation* that its able viewer, assistants, or workmen were able to make, *as deposed in*

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[m] P. 10, Report of the Belgick Commission, 25th April, 1840.
[n] Parliamentary Evidence, 2,558.
[o] Idem., 2,735, 6, and 7.
[p] Idem., 3,428, and 9.
[q] Idem., 3,503.
[r] Idem., 3,402.

their sworn evidence before the jury, who for ten days had the case under their cognizance, *was able to account for that accident unconnected with the Davy lamp.*[s]

The evidence is strongly corroborative of the now known liability of this lamp to kindle explosive mixtures under the circumstances detailed. It is probably owing to the extensive and destructive nature of these tremendous explosions of the north, where there is no vestige of such an origin, except indirect circumstance, unlike the partial fires of the other coal districts, that all direct evidence, as at Wallsend, is put beyond human investigation.

The circumstances at Wallsend are :—" That an extra discharge of gas had taken place the previous day ;"[t]—" that the Davy lamp fired at the *broken* the day before"[u]—that according to John Bell, hewer, " *the day before the accident* took place the pit was in so dangerous a state that they were obliged to come away. They (himself and five men working with him) extinguished their Davy lamps before leaving, except one man, who reduced his light as small as possible, so as to give them light to find their clothes before leaving. The lamps became red-hot, and they extinguished them as soon as possible." On the morning of the explosion, before Bell left work at eleven o'clock in the forenoon, " *all the six Davys were on fire.*" Two of the lamps were produced at the inquest, and appeared, says the coroner, " *to have been subjected to intense heat.*" Bell warned Lawson, the deputy, to be cautious. The explosion occurred about three hours and a half after Bell left, these circumstances continuing to exist.

Rutherford, a hewer, says :—" Buddle (another hewer) came to him before he had done his work, and said his lamp had fired." When he left he " told the boy to be careful in filling the coals ;" and " he never found the pit in so bad a state as she was after the fall on the 17th." Swan, another hewer, states :—" When he first commenced work on the morning of the 18th, he placed his " *Davy lamp near the roof, and she immediately fired ;* he then took the lamp down, and *cautioned the men to be careful with theirs.*" " After he had worked for an hour, he put his Davy lamp up again, near the same place, and *she fired again.*" This was the morning of the explosion. When he left his work he did not consider the pit safe. " He told Simpson, the back-overman, to caution the boys to be careful." The boys and men still employing only Davy lamps.

Here, then, is danger apparent, the men forewarned,—anxious,—alarmed,—here are two days warning,—increased precaution, and nothing but Davy lamps,—the lamps then on fire,—red-hot,—these the last living accounts from the pit,—then comes explosion, and all further trace from its sweeping destruction lost. Knowing the contingency, the facility with which flame may be passed through the gauze, and now, in addition, the existence of the gases, sulphuretted hydrogen, and olefiant,[v] that at the dull red-heat of a burning Davy would explode the whole mine ; this dreadful catastrophe cannot properly be ascribed to any insane conduct of any being, at such a time, but to the Davy lamp itself.

But even admitting the possibility of Wallsend explosion being produced, contrary to this body of evidence, by some other cause ; the irrefragable proof adduced of the Davy lamp effecting explosion, in the numerous instances stated, for ever sets the question of its absolute safety at rest.

The Davy lamp absolutely unsafe.

Considering, then, that the Davy lamp has been found by *experiment,* and *in practice to explode the external gas,* by the passage of the flame through the gauze ; and that a dangerous contingency is produced when the lamp is hot, to which it is peculiarly liable, no doubt can remain that it has been the cause of some of the hitherto unaccountable accidents which have occurred; that, therefore, its employment is far more *uncertain* and *dangerous* than the friends of humanity and science at first anticipated, and that it has too long possessed the unlimited confidence of miners in its protective powers.

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[s] Mr. Buddle stated at the coroner's inquest, " That he knew no more than a child where or how the accident originated ;" and in his evidence to the Parliamentary Committee, he says,—" I have never yet found our fresh air returns in this unfortunate mine, in a dangerous state, that is to say, the *ventilation in the candle districts or whole workings was always perfectly safe.*"—2,192.

[t] The overman, Mr. J. Atkinson, jun.'s evidence.

[u] The underviewer, Mr. Atkinson, sen.'s, evidence.

[v] Occasionally also free hydrogen.

STEPHENSON'S LAMP.

STEPHENSON'S LAMP consists of a wire gauze, about 5½ inches high and 2¼ diameter, with a glass cylinder inside. The air for combustion is supplied through a triple circle of small perforations in the metal bottom, secured from external injury by the oil vessel which screws over them, leaving, however, about ⅛ of an inch for the passage of the air to the perforations. On the top of the glass cylinder, inside, is a sort of metal chimney, full of small holes, like the top of a pepper-castor.

This lamp gives a steady light by being protected from the currents of the mine; but is liable to have its supply of air diminished by the perforations becoming choked with the oil, as well as small particles of dust and coal: from this cause its light frequently burns dim, and sometimes nearly is extinguished, which renders it therefore less certain for continued employment. This will be more fully shewn when the Upton & Robert's lamp is treated of.

Stephenson's lamp, when tested before the House of Commons' Committee with an explosive mixture of 4 measures of hydrogen and 1 of coal gas, passed the flame through the apertures in the bottom with more facility than through the Davy gauze; indicating on this point inferior security.

And, as free hydrogen[w] has been found in mines with carburetted hydrogen, neither can Stephenson's be denominated a safety lamp; but when such a contingency arises, it appears will risk the explosion of a mine at least as easily as a Davy. In addition, this lamp is also liable to have its gauze top sufficiently heated to originate explosion by the ignition of olefiant and sulphuretted hydrogen gases; another serious contingency which it holds in common with the Davy lamp. Its chief advantage over the latter lamp appears to be in securing, by means of a glass cylinder, the flame from passing by a lateral current of air in an inflammable atmosphere. It also possesses a steadier light while the perforations are kept perfectly free, but which it is very difficult to do; and it perhaps becomes sooner extinguished in a foul mine than a Davy: although this Committee has seen it in an experiment, continue to burn, with an elongated flame, sufficient, in a short time, to red-heat the top.

Should the glass cylinder get fractured, it then becomes a common gauze lamp, with, however, too large a capacity of gauze cylinder to be safe in an explosive mixture, its internal diameter being not less than 2¼ inches; from the volume of gas it would contain, it would be very liable to explode through the gauze, as well as expose its top sooner to a red-heat: a large cylinder going into that state sooner than one of smaller diameter.[x] The Davy lamps employed are not considered safe over 1½ inch diameter. These contingencies of the Stephenson lamp cannot be said to detract from the well-earned fame of its distinguished inventor, who, side-by-side with the great British chemist, has, to the extent it will permit, made and applied this beautiful discovery to most valuable purposes of humanity.

Smith's lamp.

Stephenson's lamp, with certain modifications, is in use at several collieries in the north. An improvement of it, now before the Committee, by Mr.

[w] Parliamentary Evidence, 5 and 4,224.

[x] See a paper of Sir H. Davy on the combustion of explosive mixtures, read before the Royal Society 25th of January, 1816.

Preferable to the original Stephenson's.

Henry Smith, the director of Mr. Watson's works at Newcastle, an extensive maker of Safety lamps, is becoming generally employed instead of the old lamp in such collieries.

The improvement consists in passing the air through the wire gauze, as well as the perforations which are placed in this lamp on the under side of a shoulder or rim, which is around the lamp near the bottom; its upper part the segment of a circle. The apertures, thus placed, are free from exposure to dust or oil. The interior of the shoulder is a hollow chamber, fully open interiorly, over which the gauze of the cylinder is stretched; thus affording, as in Upton & Robert's lamp, the security of perforations and gauze at right angles with each other against the passing of the flame. This is an exceedingly ingenious and well-contrived lamp, infinitely preferable to the original Stephenson's, both for safety and continuance of light. It has been in existence upwards of two years, and seems to have preceded a something similar improvement of Monsieur Lamielle, of Belgium, whose ingenious lamp the Belgick Commission so favourably reported on in 1840, and which this Committee will, in its place, more fully examine.

The Clanny Lamp.

The Clanny lamp, produced before the House of Commons' Committee in 1835, had for its body a common Davy, to which is attached an apparatus for extinguishing the flame from an explosive mixture, when it is of sufficient strength to extend itself high in the lamp.

Dr. Clanny's Shield Lamp.

This apparatus is an extinguisher covering externally the entire lamp when down except about ¾th of an inch at the top; also leaving a small space at the bottom of the lamp for admission of air, by having its circumference a little larger than the gauze. The extinguisher is composed of three brass cylindrical shields, sliding over each other like the divisions of a telescope, exposing, when pushed up, about ⅔rds of the gauze lamp; a thin filament of brass wire is then passed transversely through the body of the lamp to support the shield. Whenever the lamp is placed in an inflammable atmosphere, the extension of the flame up to the wire fuses it, and the shield drops down and extinguishes the gas flame, leaving the oil lamp only with a very diminutive light, which enables the party to find his way from the place.

This ingenious contrivance of Dr. Clanny does not secure against the passage of the flame through the gauze. In this point it acts in a similar way as a common Davy lamp: in an experiment before the Committee of the House of Commons with 4 measures of hydrogen and 1 coal gas, it was instantaneous. This description of lamp will not then guard against sudden blowers of gas or strong currents. Therefore this invention of Dr. Clanny is not a safety lamp, and can only be useful to indicate an inflammable atmosphere and warn off the workman inattentive to his lamp. The nicety and delicacy required in the management of the wire and apparatus, it is to be feared, can scarcely be expected at the hands of the rude miner, who, in the habit of using the naked gauze lamp in all descriptions of fiery atmosphere, would probably reduce Dr. Clanny's lamp to the same condition, which can easily be done, whenever he might employ it in the mine.

Dr. Clanny's new invention and improved lamp.

Dr. Clanny has, since the Committee commenced their labours, placed in their hands a much more ingenious lamp, on scientific principles, of a higher order and practically much safer than his last lamp or the common Davy. In a paper read to the Committee, explanatory of his new invention, (on the 17th August, 1839,) the Doctor assigns the following as part of the reasons that influenced its suggestion and construction.

"The diffusion of heat through gases is effected, in a great measure, by the motion of their particles amongst each other. We are indebted to Dr.

Priestley, Dr. Dalton, and Professor Graham, of London, for much valuable information in respect to the diffusion of gases; and from the valuable experiments of the last mentioned Philosopher, we are assured that the same quantity of different gases escapes in times which are exceedingly unequal, but have a relation to the specific gravity of the gas. The light gases diffuse most rapidly: thus hydrogen escapes five times quicker than carbonic acid, which is 22 times heavier than that gas. In the case of an intimate mixture of two gases, the most diffusive gas separates from the other and leaves the receiver in the greatest proportion. Volatile bodies rise into the atmospheric air, as well as into a vacuum, and obviously according to the law by which gases diffuse through each other. Heat is conducted by air in the same manner that it is conducted by water and other fluids, namely, at low temperatures by communication only, and at high temperatures by the effect of the diminution which the weight of heated molicules or particles undergoes, and by the motion in ascent thereby imparted. It is a law deduced from the physical properties of gaseous bodies that the velocities of gases, flowing under like circumstances into a vacuum, is inversely as the square roots of their densities, which is precisely the same law that regulates their flow into each other. Holding these facts in view, I constructed my new safety lamp, and by experiment I found that just within the glass and opposite the flame the temperature was 108° on Fahrenheit's scale; and between the top of the rim and of the wire gauze cylinder the thermometer indicated 302° of temperature; I need scarcely remark that in all lamps the air is constantly changing, and that in this safety lamp the *operation of the high temperature causes the expansion and diffusion of fire-damps, or of any other inflammable gas which may surround it; whilst, at the same time, a very small quantity of inflammable gas will find its way to the flame of the oil lamp, but will be diffused into the atmosphere.*"

The supply of air from the top of the lamp.

To produce this result Dr. Clanny constructed his new lamp with an impervious metal shield, having glass and lenses in its sides, only open at the highest part of the gauze cylinder for about $1\frac{1}{2}$ inch from the top, and surrounding the lamp entirely to the oil vessel: the shield being in diameter fully $\frac{1}{2}$ inch more than the lamp. There is, consequently, no admission or egress of air but *only over the top of the shield* at the highest part of the lamp. The Committee experimented at different times in the mine with this new construction of Dr. Clanny. From the first lamps having had window glass in their sides several accidents occurred, rendering them simple Davy lamps; the lamp with the lens burnt well, but was deficient in light, owing to the rest of the shield being entirely metal. In an experiment at Wallsend by the Committee, accompanied by Mr. Buddle, in a strong air course the Davy lamp and Upton & Roberts' were extinguished by the force of the current, while this lamp of Clanny retained, from its protecting shield, its light unaffected. When these three lamps were tried at the same pit, in a feeder of gas, Upton & Roberts' first exploded itself out, then the Davy with a slight audible explosion, whilst this Clanny lamp did not appear much affected by the gas; although the light was so imperfect as to show only a glimmer through the lens.

In several trials it continued to operate in a similar manner, but the light was invariably so small as to be inapplicable to the purposes of practical mining.

Dr. Clanny has, however, since the above period, made an alteration on that point which obviates entirely the obstruction of light by the metal shield; he has substituted for that part of it opposite the flame a thick globular shield of glass, which reflects the light in a very perfect manner, the metal shield being continued from it upwards, as before explained, nearly to the top of the gauze cylinder; receiving its supply of air to support combustion *exclusively from above*, which, at the same part, emits the decomposed air. At first sight it appears singular that the entire of the interior within the shield should not be filled with nitrogen, carbonic acid gas, &c., and the light thereby extinguished, which invariably takes place when an external shield is made of so small a diameter as closely to envelop the gauze cylinder. It is thus demonstrated, that in a lamp of this construction the air for the supply of flame passes down between the cylinder and shield, and returns up the middle of the interior of the lamp, and is thrown off at its highest part on the principle laid down by Dr. Clanny; and the air having to descend through a heated medium excludes much of the light explosive gases both from their specific gravity and their increased diffusibility from the operation of heat.

This perhaps may account, in some degree, for the steadiness and brightness with which, in a moderately inflammable atmosphere, as well as in a current, this lamp continues to burn.

There is a just objection to the risk of fracture to the glass, which is external and unprotected, and which, though of great strength, an accidental blow, or a drop of water when heated, might in an instant effect; but this, however, would then only render it a Davy lamp. A lamp which the Doctor has placed before the Committee on this principle, but with a naked projecting globe of strong glass, without any external wire gauze, is perfectly inadmissable for the reason just assigned,—the facility of fracture of the glass. Another objection made by miners to its employment is its great weight as compared with the Davy; this difficulty, it is feared, would not be easily surmounted by the wastemen, who have to travel many hours a day through narrow passages generally in a bent posture, and often on hands and knees with their lamp in hand: and even to the common miner it is a matter of strong objection amounting to dislike, but which experience would doubtless overcome.

A superior lamp.

The danger continues to exist, in some degree, in this as in other lamps, although to a greatly diminished extent,—that in a highly explosive atmosphere the upper part of the lamp becomes much heated, and thus tends to bring into operation the contingencies of explosion by olefiant, sulphuretted hydrogen, or hydrogen gas; and, therefore, though a vast improvement, neither is this most ingenious and scientific lamp the desideratum so much sought after—*in all points a perfect safety lamp;* yet in principle and operation it is infinitely superior to any the Committee have yet examined.

Upton & Roberts' Lamp.

The Committee were surprised to find, notwithstanding the strong recommendation of the lamp of Upton & Roberts by the Parliamentary Committee in 1835,[y] that not a single mine of the north, five years afterwards, had adopted it.

In a letter to the Shields Committee of date London, 8th August, 1839, Mr. Upton writes,—" I beg to say, most unreservedly, that I consider the Davy lamp a most destructive instrument, inasmuch as it is held out to be a safeguard under circumstances where it is signally insecure. The trial before the Parliamentary Committee ought to have been quite sufficient. *It required unhappily, however, the sacrifice of hundreds more to expose one of the greatest fallacies, if it be now exposed, that was perhaps ever practised on the credulity of mankind.*" " In reference to our (Upton & Roberts') lamp, I beg to say that I shall take care one shall be sent. It might perhaps be expected that I should say something as to the qualities of this lamp. I will do so with as much candour as I can. Its safety is undoubted, and it is now in use in many of the Staffordshire mines, and, I believe, is found a useful as well as a safe instrument. I am, however, willing to admit that I think it might be improved in several minor respects, and I fully hope, possessing as it does so estimable a quality as perfect safety, that it will not be long considered unworthy even in the northern districts of having many improvements suggested by experienced persons. *The patent will be out next May, when it will be open to the whole trade, and have, I hope and trust, its capabilities turned to their proper account.*"

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[y] They report "that they are decidedly convinced that its (the Upton & Roberts' lamp) construction possesses paramount merit," and that it appeared to them "to provide against all, or nearly all the contingencies attending the Davy lamp."

While the Committee of the British House of Commons declares this lamp so constructed as "to provide against all or nearly all the contingencies attending the Davy lamp;"[z] the Commission at Liege, for experimenting upon it and other lamps, instituted by the Belgian Minister in 1836, in their last report, (the 23rd April, 1840,) after four years' enquiry, speak of the safety of the Upton & Roberts' lamp, if possible, in still higher terms:—

"Qu élle est de sureté, en toutes circonstances, dans son etat normal, puis qu' élle resiste a l' hydrogène pur, et que sa construction est telle que la toile mêtallique est completement garantie de l' action des courants d' air, et que vu la difficulté de l' accés de l' air ambiant, la combustion du gaz ou de la meche ne peut y devenir assez active pour porter la toile mêtallique a une temperature inquietane; qu élle serait encore de sûreté, au même degré que celle de Davy, lorsq' ún accident quelconque viendrait a la priver de l' envelloppe de cristal qui entoure la partie inferieure de la cloche metallique, &c. &c."

Here at length it was hoped that humanity and science had triumphed completely, and that the fate of the miner would, for the future, be secure in his own hands. This hope, which sprang so brightly forth, has, it will be seen, been again for a time disappointed.

Description of the lamp.

The Committee in placing on record, which is necessary here, the description of Upton & Roberts' lamp, will take that forwarded by Mr. Upton himself. It consists of a cylinder or cage of wire gauze, as in the Davy lamp, 5½ inches high and 1½ diameter, over which, enveloping it externally, is a glass covering. The air is admitted through horizontal apertures immediately over the oil vessel, and then is passed through a double layer of horizontal gauze, two moveable disks, which forms the bottom of the lamp, in the centre of which the wick rises; the whole of the air being turned on the flame of the wick by means of a cone, the circumference of whose apex surrounds the lower part of the flame. The gauze top is doubled, as in the Davy, by a cap; and there is, in addition, a metal chimney 2½ inches high, 1¾ in its base, and contracting at its throat to 1¼ inch, with large perforations near the top to emit the smoke and decomposed air. This chimney screws down closely upon the external glass covering, which is 4½ inches high.

When the lamp is lighted the air passes through the horizontal apertures, and then takes a direction at right angles upwards, through the double gauze bottom directed by the cone on the wick; and the air seems ruled in its admission to the lamp by the supply required to feed the flame. In an explosive atmosphere, by its restricted admission to the flame, it is nearly all consumed as it presents itself, and it is scarcely possible to fill the lamp with it: whatever escapes without passing the flame is so vitiated and rendered incapable of supporting combustion by the nitrogen and carbonic acid gases rising in the lamp, that no gas-flame ever reaches high in the interior of the cylinder; if in a very fiery mixture, slight explosions occur, and the light is speedily extinguished. Thus there is no cause to apprehend, under any circumstances, the possibility of over-heating the gauze top: the Committee have found it impossible to effect it in the most fiery mine, and there is no explosive mixture that can be made to pass the flame upwards, while the glass secures it against currents of air or of blowers; extinction by inflammable mixtures, and not explosion, being its principle.

The chimney, by being contracted, bears a proportion for the exit of the air after combustion to the perforations, gauze, and cone, for its admittance; thus preventing a rush through the apertures below on the flame, which would either extinguish it or escape into the lamp unconsumed, and in an inflammable air burn to over-heat the lamp. The contracted chimney also keeps an atmosphere of deoxygenated air, if it may be thus called, over the weakest part of the top of the lamp, doubly securing it from over-heating.

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[z] Every lamp tested before that Committee passed the flame but Upton & Roberts'; it was tried with 4 measures hydrogen and 1 coal gas; with 3 parts of air and 1 coal gas; with 6 parts of air and 1 coal gas; with 4 parts of air and 1 hydrogen; and with ⅔rds air and ⅓rd hydrogen, but passed no flame.

Its facility of extinction.

Whenever the Committee have tried this lamp in the fiery mines of the north, its delicacy was such that before the Davy lamp was much affected it usually exploded itself out: and this occurred to other lamps as well as that sent by Mr. Upton. It was impossible to fill it with flame: an indication and warning, it perpetually hinted danger.

In a goaf of St. Hilda Pit, it is stated in the minutes of the Committee, that when tried,—“ For an instant the flame burnt blue, extending up the interior nearly two inches, and then with a slight explosion extinguished itself:” this was repeated, and it almost instantly invariably did the same. In an experiment with lamps in Monkwearmouth Pit (the deepest in England), “ it extinguished itself even at a walking pace in the hand: the glass and light were smoky and dim. At Wallsend it was tried with other lamps in a feeder of gas, and “ could scarcely be brought into operation from its facility of extinction.” At Jarrow Pit, when tried in a strong blower of gas, it was the first extinguished; but such was the force that both the Davy lamp and the original Clanny’s were also blown out. At Pensher Pit, on the Wear, the current of air in the furnace drift also extinguished it. Indeed, in every instance this sensitiveness, on exposure to the slightest breath or explosive mixture, regularly demonstrated itself.

It is this very delicacy of operation which renders it with practical miners so objectionable for their daily employment in the mine. It obstructs instead of facilitating their object. A sudden dropping of the hand with a lamp puts out the light; the slightest increase of foul air bedims the glass, and then the flame gradually dies or explodes out. The horizontal gauze placed below the level of the oil wick, receives from the trimming or an accidental spark, little vesicles of oil which clog and impede the flow of air; the light then soon becomes smoky and dull, and in this case eventually dies out, or the lamp must be brought to a free part of the mine to be cleaned and re-arranged.

The Committee have frequently seen it blown out by a current of air in the gallery, and it invariably required the nicest care to keep it burning for a few hours in the different parts and states of the mines. Even a breath through the bottom perforations would at once extinguish it.

A decided objection to its practical adoption.

To ordinary workmen this difficulty is insurmountable. It would be impossible even to compel its adoption in the northern mines: the result on their produce would be seriously injurious. In the hands of careful men of science it is a perfect lamp for occasional experiments. Secure from any contingency that may arise, its glass may be accidentally broken and it resolves itself into a Davy lamp; nothing but a crushing blow will lay bare any chance of danger. But in the hands of the mere miner, intent upon his labour, and irritated from its imperfect and uncertain light, there is every probability that the most hazardous expedients would be had recourse to, and that it would become more dangerous than a common gauze lamp in his ill-judged attempts to increase or continue his light for his necessary operations.

It appears that the Belgick Commission have also observed some of these incapacitating points in their experiments upon the lamp. They state :—

“ Que nonobstant sa complication, son poids, son volume, son prix elevé (confectionnée dans nos ateliers avec toute l’ economie possible, elle couterait au moins le quadruple de nos lampes de Davy) et meme la fragilité du cristal, cette lampe (Upton & Roberts) devrait etre preférée a celle de Davy, dans toutes les mines dangereuses, si elle n’ avait le grave inconvenient de s’ eteindre, faute d’ oxygène, aussitôt qu’ un peu d’ huile s’ est répandue sur les disques mètalliques par lesquels l’ air est admis dans la lampe ou qu’ un peu de poussière est venue en obstruer les mailles ; or ce défaut a eté constaté successivement sur trois lampes de cette espece recues des inventeurs, et il serait difficile qu’ il en fut autrement, car les trous de la galerie et les disques établis au niveau de l’ orifice du reservoir d’ huile, sont exposés a s’ encrasser, au moindre épanchement. La commission a d’ ailleur pu observer que, quand le gaz inflammable est melangé en proportion notable a l’ air, l’ huile du reservoir ou du moins du porte-mêche entre en ébullition et éclabousse les toiles, sans méme que la lampe soit inclinée ; ce dernier phénoméne tient vraisemblablement à ce que le gaz brûle depuis son entrèe par les disques jusqu 'à la mèche, et produit une chaleur considerable, dans toute cette partie de la lampe." " En rèsumé, cette lampe devrait recevoir encore des perfectionnements importants, pour que la commission se crût autorisée a en proposer la substitution à celle qui est en usage dans nos mines à grisou."[a]

The Committee cannot quit Upton & Roberts' lamp without the deepest regret that their duty will not permit them, after their own practical experiments in the mine, sustained also by the Belgick Commission, to recommend its general adoption ; for it possesses all the elements of perfect safety, but unfortunately from its deficiencies that have developed themselves in the mine, as above demonstrated, it is impossible to avoid the conviction that it is inapplicable to daily practical uses. Its ingenious and able authors, they trust, will, by an application of the same powers that produced it, be able to remedy the defects which the Committee have pointed out, and at length produce a lamp perfect as the present in safety and more practical in employment.

Mr. William Martin's Lamp.

This lamp is of a most ingenious construction, without wire gauze. The air is admitted like Stephenson's, through perforations in an upper metal bottom to the wick: in this instance by four circles of small apertures $\frac{1}{64}$th of an inch in diameter. The body of the lamp is a glass cylinder, 4½ inches long and 2 inches diameter; and the top consists of a copper chimney contracting gradually to a cone, something similar to Upton & Roberts'. Dr. George Fife, of Newcastle, tested this lamp before the Medical School of Newcastle, 9th February, 1836. The following are the results :—With carburetted hydrogen, or coal gas diluted, so as to produce its most explosive combination, Mr. Martin's lamp was tried:—

1st. By introducing the lamp into a glass jar containing the gas, the flame was immediately extinguished, without either explosion or inflammation of the gas within or external to the lamp.

2nd. By passing a current of the same gas upon the lamp, the same result followed. The lamp was next tried with one of the most explosive combinations that can be formed, viz., by the mixture of the coal gas, or carburetted hydrogen, with 4 volumes of pure hydrogen gas. In the first trial, from Mr. Martin's lamp not being properly secured, the lamp, on immersion in a glass jar, exploded. On a repetition of the experiment, and in a much more concentrated manner, viz., by directing a strong current of the gas into the lamp, the flame was almost immediately extinguished, and without the slightest detonation.

This lamp, like that of Upton & Roberts, is peculiarly delicate, and extinguishes itself almost on the approach of carburetted hydrogen, as was found on trial by the Committee in a foul part of the mine; and as the use of lamps is intended, under the present system of working mines, for a fiery atmosphere, and not as a mere indication, this lamp would not be operative for that purpose. There is also an insuperable objection, as remarked previously on one of Dr. Clanny's lamps, to a glass cylinder without gauze, as there is a risk of fracture from several causes, that renders it inapplicable, or, at least, most exceptionable, in a fiery mine.

Mr. Richard Ayre's Lamps.

Mr. Richard Ayre, of Newcastle, has also constructed two ingenious varieties of the Davy lamp; one to extinguish the light in any attempt to unscrew it; the other, what he calls a Barometer lamp, in which the air passes through a valve which shuts itself, as the atmosphere becomes light or filled with foul gas, and then extinguishes the lamp. There are some other modifications of Safety lamps, which, although ingenious, yet not being conveniently practical, it is unnecessary at present to dwell on.

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[a] Rapports adressès a M. Le Ministre des Travaux Publics, par la Commission instituée a Liege pour l' essai des lampes de mines. 1840.

BELGIAN LAMPS.

Genius and humanity are exclusively of no country; to the honour of man they are inherent in his nature, they take up their abode wherever he is found and only require favourable opportunities and circumstances for their development.

The Belgick Government, inspired by the exertions and limited success of the friends of humanity in England, as demonstrated by the Parliamentary inquiry—and deeply interested in their own mines, a source to them of much national wealth—instituted a Commission to inquire into Safety lamps. The result has been the invention of two ingenious modifications of the Wire Gauze Safety Lamp, which by that Commission has been most favourably reported of. M. Van de Weyer, His Belgick Majesty's Ambassador in this country, has done the Committee the honour to procure those lamps from Belgium for them to test in the mines of England.

The Mueseler Lamp.

Its description and principle.

This lamp stands about 10 inches high, including its oil vessel; and its external diameter is, from 5 inches upwards, about $3\frac{1}{2}$ inches. This great diameter is owing to a sort of shield, of eight ribs of iron, placed edgeways, vertically covering a very strong glass, $\frac{1}{4}$ of an inch thick, formed like an ordinary drinking glass, without a bottom, which is $3\frac{1}{2}$ inches high, and $1\frac{3}{4}$ internal diameter. This glass is placed around the flame of the lamp, excluding all air except *over its top,* which is covered with wire gauze, but *without any other gauze internal or external;* it is thus a naked glass except the eight vertical ribs of iron, which are each an inch apart. Placed upon the glass, and as a continuation of it, is a wire gauze cylinder, $4\frac{1}{2}$ inches high, and $1\frac{3}{4}$ internal diameter, having a brass top full of minute perforations. The glass and wire gauze, closely united, make a continued cylinder about 8 inches in height; having a piece of wire gauze stretched across the internal area at the junction of the two substances, over the top of the glass, as above stated. Through the centre of this piece of horizontal gauze there is a small metal chimney to convey from the flame of the lamp the smoke and deoxygenated air; it passes down to within an inch of the wick; is 4 inches high, about $\frac{7}{10}$ths in diameter below, and $\frac{4}{10}$ths above, and rises to discharge the smoke, &c., about half way into the interior of the wire gauze cylinder.

The Committee have been thus particular in the description of the "Mueseler lamp," because the Belgick Commission consider its superiority undoubted over the Davy, Upton & Roberts', and every other lamp hitherto invented: and that its principle is new, its safety perfect, and its light surpassing all others.

When this lamp is set in operation, the air to supply the flame passes *from above downwards:* first through the gauze sides of the cylinder above, and then through the transverse gauze on the top of the glass; and when it has performed its office, it ascends through the chimney in the centre exactly over the wick.

The effects appear to be similar to those in the improved Clanny lamp, described a few pages back, wherein the air enters at the upper part of the lamp. The air in the lamp is kept freer than in the Davy or other lamps;

Its good qualities.

its current stronger, and its light better. It, however, more easily explodes itself out than the Clanny lamp when the inflammable mixture is of considerable strength. The flame cannot pass by explosion, as, in addition to the almost impossibility of surcharging a lighted lamp of this description with gas, there is no egress but over the top of the glass through the transverse gauze, and then again through the sides of the gauze cylinder at right angles with it, thus completely guarding it against this danger. But the flame can scarcely long exist from a certain delicacy which the lamp possesses when immersed in an explosive mixture, for it speedily explodes itself out.

On trials with the Mueseler lamp in the month of July, 1841, and since in one of our most fiery mines, the Committee found the light very good, unaffected with currents; and when placed in a recess of the "*broken*," in which much gas existed, it gave slight audible explosions, and immediately extinguished.

The Belgick Commission thus speaks of this lamp :—"Elle a soutenu les èpreuves de la maniere la plus satisfaisante, et a etè unanimement considerèe comme reunìssent, a un plus haut degrè que toutes celles essayèes jusqu' ici, les conditions essentielles d' une bonne lampe de sureté. *La commission a vu un perfectionnement d' une grande portèe dans la disposition qui consiste á faire arriver, par le haut, et non par le bas, l' air destiné a la combustion de la meche*, et á combiner les choses, de telle sorte que, lorsque l' air contiént une quantitè de gaz inflammable capable de faire craindre une explosion, et par consequent d' activer momentanément la combustion outre mesure ; le premier effet de cette activité extraordinaire soit d' alterer cette composition dangereuse de l' air entrant, en y mélant dans une proportion notable, une partie des gaz brulés ; ce qui non-seulement rend impossible toute deflagration, mais contribue encore à la prompte extinction des parties en ignition."[b]

Clanny's priority of discovery over Mueseler.

The principle so much approved of by the Commission, in the above extract, of supplying the wick of the Mueseler lamp by air from above and not from below, it is but justice to Dr. Clanny, and in accordance with truth, that this Committee repeat here, that, in a paper publicly read to them on the *17th August*, 1839,[c] already examined, in which Dr. Clanny explained the construction of his new lamp, passing the air *downwards to the wick* from the summit of a shield nearly covering the entire gauze, was the principle on which it was based. It was tried by this Committee in the mines at the time, and published in the journals of the day, and M. Mueseler, according to the Belgick Committee, did not offer his lamp to their examination till they were about terminating their labours in August, 1840 ;[d] and the 18th of August, in that year, was the first time that the Commission experimented with it. Consequently Dr. Clanny possesses the undivided merit of the discovery and application of this principle, and had, upwards of a year, a published priority of it over its adoption and application by M. Mueseler.

The Belgick Commission, after trying the Mueseler lamp with various explosive mixtures, terminate their report of it thus :—" Il est aisè de juger, par l' èloge qui precede, que si la commission devait se prononccr aujourd' hui, a se sujet, elle ne balancerait point à donner la palme à la lampe Mueseler."

A naked glass cylinder a strong objection.

This preference of the Mueseler lamp, by a scientific commission employed upwards of four years investigating Safety lamps, including the Upton & Roberts, the Davy, and all other meriting attention, deserves to be received with the utmost respect for examination in England. This Committee have consequently given it most attentive consideration and trial, and have already accorded it improved light and safety from explosive mixtures passing the flame to the atmosphere around ; but most decidedly they object to its general application with its naked glass unprotected by wire gauze. Already they have refused to admit even for consideration two most ingenious lamps, one of Dr. Clanny, and another of Mr. Martin, on the same principle of glass, without gauze, forming the security of the lamp. The facility with which glass may be fractured either by a blow, splinter of coal, fall, or any other such accident, as well as by a single drop of water, when heated, which the glass of the Mueseler lamp would be very liable to, especially in a fiery wet mine; renders a lamp of such construction in a most material point, unsafe. A case quoted by Sir H. Davy corroborates the certainty of this danger.

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[b] Second Rapport par la Commission institué a Liége 1840.

[c] See preceding pages 18, 19, and 20, on Dr. Clanny's Safety lamp.

[d] Second Rapport, &c. &c.

M. Gossart, President of the Chamber of Commerce of Mons, in his report on the Safety lamp, states,—"That a director of the works having descended into the Colliery of Tapatouts *with a lamp, of which the base of the cylinder," like the Mueseler lamp, "was of glass, a drop of water fell upon and broke the glass,* and detached a piece which would have opened a communication for explosion; but the air fortunately at that moment was not adulterated with fire-damp." A visit to a glass work will show at once how a drop of water, or even the surface of cold steel, will instantaneously separate masses of hot glass nearly an inch in thickness. To such a probable contingency as the fracture of a glass cylinder, then this Committee are unwilling to commit the safety of a whole mine; and must refuse the Mueseler lamp their sanction till in this point it is amended. There is also another objectionable point to its regular employment:—Should the flame, by holding the lamp at an angle, not be immediately under the chimney, and the vitiated air escape into the lower part or chamber of the lamp, it is at once extinguished; this is an accident that is likely to occur very frequently in the hands of workmen who are in the frequent habit of carrying their lamps by their sides and oil vessels, and not by the ring at the top. This would originate attempts at re-lighting, if far from a naked light in a dangerous part of the mine, that would probably lead to perpetual serious risks.

Another point of some importance is the great weight of the Mueseler lamp. Already have strong objections been made to some of the improved lamps by viewers and others on this ground.[e]

Weights of the different lamps.

Where wastemen and other officers, for perhaps six hours a day, are obliged to be examining the most dangerous parts of the mine, lamp in hand, frequently in narrow passages, in contorted postures, the weight of the Mueseler lamp being twice that of the Davy, gives a show of reason to such objection. The following are the respective weights of the several lamps:—

	℔.	oz.
The Davy Lamp weighs	1	6
The Mueseler Lamp	2	11
Dr. Clanny's Improved Lamp,	2	6
Upton & Roberts' last Lamp	2	0¼
Stephenson's Improved, in use at several mines	2	3½
The Lemielle Lamp	1	10½

To the men stationary at their work this point is less important, nevertheless amongst them all there is a strong disinclination to the employment of a heavy lamp. Hostile opinions on such particulars, it is, however, possible to surmount; but a vital error on the principle of safety it is impossible, nor would it be proper to attempt to overcome. The Committee therefore regret that the insecurity of the Mueseler lamp, from naked glass forming part of its cylinder, renders it impossible for them to recommend its employment, as at present constructed, in the English mines.

THE LEMIELLE LAMP.

The *Lemielle lamp* is a simple construction of much ingenuity: it is a Davy lamp, with a glass inside, admitting the air at the bottom through a treble gauze, in an improved mode. Its gauze cylinder is 6½ inches high; $1\frac{4}{10}$ths internal diameter, without any double top or cap. There is a glass cylinder internally fitting the gauze very tight, running upwards more than half-way,—for $3\frac{3}{4}$ inches, very strong, and its internal diameter is $1\frac{1}{10}$th inch : this glass is fixed within the gauze cylinder by a small metal button. The bottom end of the gauze is reflected outwards all around, at right angles, and has, in this reflection, a treble gauze, which forms a broad rim or bottom on which to support the cylinder, standing out from the latter, around its entire circumference, about $\frac{3}{4}$ of an inch. The oil vessel has the top of its circumference elevated about $\frac{3}{10}$ths of an inch, on which the rim of the cylinder is placed, and the wick then rises into the glass about $\frac{1}{2}$ an inch, leaving only the brass top of the oil vessel below to receive falling particles of oil. There is a strong frame, as in the Davy, to screw down and secure the several parts of the apparatus in their places. In this case, however, the gauze rim is merely covered by a projecting piece of brass, without being close to touch the gauze, that it may protect the former from the dust falling upon it, and at the same time secure the passage of the air beneath it, which only has admittance through the horizontal transverse gauze rim. The frame merely presses the extreme circumference of this gauze rim upon the circular elevation of the oil vessel about $\frac{1}{8}$ of an inch all around ; it is thus fixed and kept in its place, and is free for the passage of the air. The effect of this construction, when in full operation, is, that the air which in Stephenson's Improved lamp passes through vertical gauze to the wick; and, in Upton & Roberts', through a double gauze on the top of the oil vessel from below upwards; in the Lemielle lamp, passes downwards through the treble gauze rim into the space between the top of the oil vessel and wick, then again up to the wick in the narrow glass cylinder. There is here, in this Belgick lamp, a complete change of direction of the air supplying the wick, amounting to reflection, and a security of the gauze through which it passes from dust or oil, keeping it free, and the light generally, especially at the first, very good. The narrowness of the glass cylinder probably induces a greater current and brighter light, and consumes the fire-damp by bringing the whole air under the influence of the flame. On several trials with this lamp the Committee found it burn well in a vitiated atmosphere, unaffected by currents, and when brought into an explosive part of the mine it extinguished its flame by a very trifling explosion. This is a lamp of very good properties, and is also much recommended in the report of the Belgick Commission. Those prepossessed in favour of the Davy lamp will be able to perceive very little difference in appearance, and it is only about $4\frac{1}{2}$ oz. heavier.

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[e] Parliamentary Evidence, 2,284.

Its description and qualities.

The Commission, after they had suggested certain improvements, as the triple disk and smaller space between it and the oil vessel, reports :—" Que la lampe de M. Lemielle, munie des perfectionnements qu il y a apportés, a la suite des observations de la commission et des épreuves aux quelles elle a été soumise, doit être de sûreté, dans toutes les circonstances ordinaires de l' exploitation des mines." They object, and justly, to the gauze becoming choked with smoke depositions over the glass cylinder, obscuring its light, and from obstructing the circulation of the air, they might have added, it will eventually extinguish it. It, however, passed an explosive mixture of hydrogen and air; but this defect they remedied by a triple disk, of very fine wire gauze, through which the air was passed into the bottom of the lamp to supply the flame. Another more fatal objection : the upper portion of the cylinder becomes strongly heated from an inflammable mixture when not sufficiently strong to effect internal explosion and extinction, and this originates the contingency of mine explosion by the gases, inflammable at red-heat of metals, as before demonstrated.

Objections to its employment.

This lamp then has, in addition to the dangers of exploding through the gauze bottom, if the disks are not sufficiently fine and numerous, a highly inflammable mixture and external inflammation by a heated gauze cylinder, the obscuration of the lamp by depositions of soot, that rapidly take place on the gauze above the glass and on the glass itself rendering it for ordinary employment troublesome, inconvenient, and dangerous. Therefore the *Lemielle* lamp, with all its ingenuity, cannot be well admitted as a safe substitute for the other improved lamps already in use. And the Committee regret that neither of the two Belgick lamps, with which they have been favoured, supplies the desideratum of a perfect safety light under every contingency of a fiery mine.

And thus terminates the Committee's examination of the safety lamps, which have individually received their most anxious and careful attention, as a matter of the first consequence to the object of their inquiry.

The Committee's general conclusions on Safety lamps.

The Committee have now to report, after the most minute investigation and experiment which they have been able to devote to this branch of their subject, that in their opinion no mere safety lamp, however ingenious in its construction, is able to secure fiery mines from explosion; and that a reliance on lamps alone is a fatal error, conducive to those dreadful calamities which they are intended to prevent. The Committee further report, that they are of a decided conviction, according to the foregoing premises, that the naked Davy lamp is, without a complete shield, a most dangerous instrument, and has indubitably been productive of those accidents in mines against which it is still too confidently and generally employed, at the daily imminent risk of producing a like calamity.

The principle of the Clanny and Mueseler lamp, the safest.

The Committee are further of opinion, which coincides with that of the Belgick Commission, that the best description of lamp to be employed is that on *the principle of the Improved Clanny* and *the Mueseler lamps, the latter with a continuous gauze cylinder*; but that the utmost attention must be paid always to their condition, and more particularly to those of other descriptions: that the gauze must be examined daily, and every part of their construction be ascertained to be perfect; that the workmen must be warned never to continue working in an inflammable atmosphere with their lamps over-heated by increased flame; and that instead of being impressed with the idea that they are absolutely safe instruments, they should be convinced that they are only comparatively safe, and contingencies may easily arise in which even the best constructed may be productive of danger and explosion.

The Committee regret to observe, that from some erroneous conviction or other less defensible cause, this mode of securing safety in mines has been beyond all reasonable bounds relied on, while the far more important and safe system of *ventilation* has been comparatively neglected.

VENTILATION.

VENTILATION seems to be the only certain and secure means of safety in inflammable mines. It is depended on more or less in every case; but since the discovery of safety lamps it appears to have sunk to a certain extent into a secondary, instead of continuing the great primary means of security against explosion.

Bad ventilation, and its effects.

To such an extent has this erroneous and mischievous neglect of ventilation proceeded, that, as an instance, there is a mine, within three miles of Newcastle, that at one time was worked with *five* shafts, about 6 feet diameter each, which, though now more extensive and in the *broken*, is only worked with *two*. The consequence is, that the workings being of old standing, and the ventilation very small, carbonic acid gas pervades to a great extent, and the men are unusually sickly, pale and emaciated for want of good air. This is no solitary case, but an indication of the general system, which will be seen as this report proceeds.

The first report of the Children's Employment Commission, 1842, page 50, says, on this subject:—"In pits with a rapid circulation the men respire more freely, the road-ways are kept dry and repaired at less expence, and the timber lasts longer by years, and therefore it is a matter of strict economy to ensure a good ventilation. In some mines the air can scarcely be perceived to move at all, a thick mist or fog pervading the whole pit, which is caused partly from fermentation in the wastes and old works, partly from the lights, and partly from the heat and effluvia from the horses and men. This, with a large proportion of carbonic acid gas, forms an atmosphere that none but colliers, who are accustomed to it, could endure, but which has the effect of shortening their days."

M. Triewald and M. Jars on natural ventilation.

M. Triewald, in Sweden, as early as 1740, and M. Jars, the French academician, in 1764, endeavoured to elucidate the art of ventilation of mines; and the latter laid down principles, and scientifically explained natural ventilation, which had hitherto been but little understood. Nevertheless, he seemed not to comprehend the immense force of artificial ventilation *by fire*, and merely suggested (in his Fig. V.) as a means of producing circulation of air in spring and autumn, when the temperature of the mine and atmosphere approximated, a small furnace and chimney at the top of one of the pits; but in winter and summer, when the equilibrium of the columns of air of the two pits were disturbed, (one being a longer shaft than the other, naturally or artificially by a chimney erected over it,) then there was no occasion, he seemed to consider, for the application of the furnace.[a] In the present state of the mines of Europe, especially of England and Belgium, with their extensive galleries and passages, extending, in some cases, upwards of 70 miles, it would be impossible to effect safe ventilation in them by the simple means suggested by M. Jars.

Furnace ventilation in 1760.

Previous to 1760, in Britain, the Furnace had been introduced at the bottom of the upcast pit; but the practice was by pillar stoppings to course the air round the extremities of the mine, were it even more than 50 acres, the whole interior workings lying "dead waste," surcharged with inflammable gas; which only required an incautious approach with a naked light, or a sudden change in the atmospheric pressure, to expand it into the air course and expose the mine to a "*blast*."

Mr. Spedding. Coursing the air.

About the year 1760 Mr. Spedding, of Workington, invented and adopted a vast improvement in the mode of ventilation, *by coursing the air through all the workings of the mine*. He turned the different galleries and workings into an enormous air pipe, through which the air was regulated by doors and stoppings, coursing it up and down each "*sheth*" or division of work, sweeping and ventilating the dead waste in the interior, and so removing the former accumulation of gas. One viewer states, that on this system he has known the air coursed from its ingress to its egress upwards of 30 miles.[b] From the immense length of course, and the consequent friction and interruption from change of direction, the current must necessarily have been very slow and sluggish; and in the latter part of its course must have been surcharged with gas evolved from the whole surfaces of the mine, that would render it, as it approached the furnace, in the highest degree explosive. This would probably be its general condition whenever the mine was in a fiery state, or had abundant discharges of gas: although it is not unusual, in long courses, to find the *first of the air*, or, after it has run a short distance, the most explosive; imputed generally by practical pitmen to the inflammable gas being imperfectly mixed with the atmospheric air. This circumstance also happens in new pits where the workings are of no great extent, when the explosions, as in Willington, in April, 1841, are of the most violent nature.

An anomaly in the pit atmosphere.

The apparent anomaly can scarcely be imputed with correctness to the gas's imperfect mixture with the air, as without the proper proportionate mixture there would be no explosion at all; and the dilution must be less than more in a long course, as the original air acquires no accession in its progress, while the inflammable gas must be increasing more or less at every yard's advance.

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[b] Parliamentary Evidence in 1835—1997.

[a] See "Observations, sur la circulation de l' air dans les mines; moyens qu' il faut employer pour l' y maintenir," par M. G. Jars, &c. &c., printed in the volume of the French Academy of Sciences for 1768, and translated by the Secretaries of this Committee, 1840.

The probable correct explanation of this phenomenon is, that a lengthened course, through extended workings of an old mine, abounds not only with carburetted hydrogen, but also with carbonic acid gas,[c] in addition to the nitrogen and carbonic acid gases from the workmen's lights and the respired air of the horses and men, which vitiate the whole column and frequently reduces it, especially towards its termination, below the explosive point.

Explosive mixtures destroyed by anti-inflammable gases.

When it is remembered that 1 part of carbonic acid gas will destroy the inflammability of 7 parts of a carburetted hydrogen explosive mixture, and 1 part of nitrogen 6 parts of the same mixture;[d] and that in an extensive mine of 150 to 200 men, with 40 to 60 horses, and a corresponding number of lights, each man alone, in respiration, giving off every minute about 26 inches of carbonic acid gas, in addition to the free nitrogen, with a proportionate increased quantity of both these products from horses and lights, besides the immense amount of the natural carbonic acid gas of the mine, it is clearly evident that all these anti-inflammable products will diminish considerably the explosive capacity of a lengthened column.

But, should the carburetted hydrogen be abundant, or the vitiation on a small scale, the mine containing little carbonic acid gas naturally, the column will rise to a dangerous explosive condition—the worse the longer its course; without, indeed, it become so surcharged with the gas as to contain one-fourth, and rise above the explosive point.

These reasons will explain sufficiently, that in long courses it is a vitiation rather than a dilution of the carburetted hydrogen in the air, that produces the less explosive capacity of the column. Were it not so, the effects should be the contrary, for the gas has a greater proportion of diluting fluid at the *winning* or commencement of the workings than when miles of excavation have been added; and, consequently, if the pit is at first more fiery, it cannot be dilution, but some other counteracting agents that destroy the inflammability in long courses. This will shew why long courses are sometimes thus less explosive than short, which also in newly-opened mines may be further rendered still more so, by the greater abundance of the pure light carburetted hydrogen, at first escaping in large quantities without intermixture with carbonic acid gas or nitrogen, while the inflammable gas, as the course is extended, at the same time gradually diminishes or exhausts itself, as demonstrated in the case of Wallsend goaf, and every old working.

The easy destruction of explosive mixtures by anti-inflammable gases, abundant or easily and inexpensively produced in the mines, might in many situations, as goaves, wastes, and unfrequented passages, be effected, it is probable, by a proper application of skill and ingenuity.

Mr. Buddle's system of ventilation.

Mr. Buddle, of Wallsend, the able pitman and distinguished viewer, introduced a great and beneficial change in ventilation previous to the year 1813.[e] Having observed the frequent accidents and obstructions to mining, on Spedding's system, by passing the whole current that had swept the mine at its termination when surcharged with gas, over the furnace, to the frequent danger of explosion, he invented a dumb furnace, or another passage to the upcast, without the foul air coming in contact with the fire at all. He then continued to further perfect his plan by *splitting or dividing the air*, not only into two ground columns, but eventually into several, as the extent or nature of the mine might require; till in October, 1839, when the Committee visited his colliery at Wallsend, its longest course was not over 4 miles in length. To such extent now has the splitting of air columns obtained in the Tyne and Wear collieries, that on a visit to Pensher, on the Wear, in April, 1840, the Committee found no course longer than 2 miles; although, in some instances, courses are in existence from 10 to 12 in extent. Dividing or splitting the air, and dumb furnaces, Mr. Buddle has had in full operation since 1815,[f] and they are now generally adopted in the north.

[c] Parliamentary Evidence, 860, 871, 1849, 3676, 3376.

[d] Davy's Researches on Flame, p. 11.

[e] See Mr. Buddle's Letter to Sir R. Milbanke, 1813.

[f] See Parliamentary Evidence, 2,002 to 2,011.

To demonstrate the principle by which the *foul returns* are made without passing over the furnace by the mere rarifaction of the upcast column of air, and which strongly exemplifies ventilation by fire: *Pensher Pit*, at 246 yards down, has a six feet furnace in the lowest (Hutton) seam; and this furnace not only ventilates the particular seam in which it is placed, but by rarifying the air in the entire upcast (the Mill Pit) ventilates the three superincumbent coal strata with their mines, (the maudlin, the main, and the five quarters' seam,) whose passages all terminate in it.

The upcast, 8 feet in diameter at 120 yards from the surface, had its air heated to 103° Fahrenheit, although 126 yards higher in the shaft than the furnace, and about 40 yards above the furnace the ascending column was at 135° Fahrenheit, while the thermometer at the pit mouth, in the atmosphere, stood at 46°.

The *difference of temperature* between the heated air of the upcast and that in any of the mines was in none of them less than 40°; in the Maudlin seam it was 72°, and nearer the furnace at the Hutton seam the difference was 140°. The consequence was, that the colder air from all the passages and galleries of the superjacent mines, as well as that in which the furnace was placed, kept pressing into the heated and rarified column of the upcast, producing currents of ventilation of as great power as are to be found in other mines of the north.

The dumb drift, and its proper exit in the upcast.

On the principle of rarifaction, and the difference in density and weight between the column of air in the downcast and passages of the mine and that of the upcast, any opening made into the latter from any part of the works has immediately a current pressed through it. Of this principle Mr. Buddle ingeniously availed himself by collecting the *foul returns* from the explosive parts of the mine and passing them by a drift (the dumb drift) over the furnace, instead of through it, to the upcast, which thus prevented any possibility of explosion at the furnace, sometimes occurring on the old system. The dumb drift, or drift for the foul returns, is always now of this nature, and is carried into the shaft 10 to 20 fathoms above the furnace drift; carrying it so high up in the shaft for securing against explosion from the furnace seems not to be quite necessary, as, for the reasons adduced a page or two back, were it even brought out only a few feet above the furnace drift, the vitiation of the air from furnace combustion would, on its intermixture, render the foul returns sufficiently inexplosive to prevent any chance of accident, even if heated matters reached it: and lower in the shaft a greater current would be necessarily obtained.

The average velocity of air currents.

The average velocity of the air through the passages of mines, on the present system in the north, *does not generally exceed three feet per second.*[g] *In many instances, where the mine is most dangerous, it is much less.*

Several mines that the Committee have visited shew a rate of circulation alarmingly small; and *which are fair examples of the system* but too prevalent amongst them.

Three or four of these extensive and important collieries the Committee will evidence, in condensed detail, to prove the condition in which they have found their ventilation:—

Tremendous extent of galleries to shaft area.

The first Example has from 70 to 75 miles[h] *of passages, and has only one pit 13½ feet diameter for ventilation, drawing coals, pumping water, and every operation necessary between the surface and the works.*

This pit, 850 feet deep, is divided for 480 feet down into three portions: *the downcast, engine, and upcast shafts;* but at that depth the engine shaft air all passes into a high seam of workings at present unemployed; and the pit to the bottom, 370 feet, is contracted in its diameter to 10½ feet, which is divided into two equal parts. One for a *downcast*, to convey the air into the low mine, thrown down by a dyke or dislocation thus far from the upper seam; and the other an *upcast* to return it after it has swept the passages and been vitiated by combustion, respiration, and the deleterious gases.

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[g] Parliamentary Evidence: Wood, 901; Buddle, 2,314.

[h] According to Mr. Wood, Killingworth Pit must have nearly 160 miles gallery excavations.—Parliamentary Evidence, 845, 1,239.

	Superficial feet.
The area of the pit, down to the high seam, is	143
But the partitions, called the *main brattice* (7 inches), and *quarter brattice* (5 inches), with the pump, reduce this area more than	12
Leaving	131
Of which considerably upwards of one-fourth forms the UPCAST, and which by actual measurement at the *settle* boards was (for upwards of 500 acres of pillar work)	36
The *engine* shaft, supplying the high seam, is	21
At 480 feet down the diameter of the pit is reduced to 10½ feet (as we have stated), which being equally divided by a brattice, 6 feet area, leaves the DOWNCAST for the whole supply of air to the lower mine of 400 acres	37

But for twelve hours a day, the most dangerous time when the men and boys are with lights in every recess of the workings, there is a further reduction of the areas of the downcast and upcast, by the area of the corf which in a colliery of only one pit is generally worked in both shafts. There are three corves at a time in each: three full coming up and three light going down. In some collieries there are only two in each shaft. In others cages and tubs are used—the latter about the same area as the corf, nearly 8 feet—and with the slides and cages take up more space than the corf. These corves take 1½ minute to ascend the 850 feet, and in about 20 seconds are in the shaft again: thus for twelve hours a day while the coals are drawing, they may be said to form a solid part of the shaft; for though when light, being strong baskets, they are partially pervious to air; when full of coals they present a resistance of their entire upper and lower surfaces. In the *downcast* they are more injurious: for ascending the shaft against the descending column of air at a rate of 9½ feet per second—the air having a velolity of only 8½—were there not a more powerful counteracting cause they would not only obstruct its entrance, but would propel it outwards from the shaft.

Each corf is area	8½ feet.
Which will leave a total clear downcast of	28½ "
And total clear upcast	27½ "

So that for this extensive mine of 400 acres, 850 feet below the surface, there is, it appears, at the most dangerous periods, only a passage of less than 6 feet by 5 square to supply the entire mine with fresh air for men, horses, lamps, and fire, as well as to reduce the inflammable gases below the explosive point.

Down the shafts described the air took 1 minute 40 seconds to descend; so that through these areas the supply is not more *than about* 30,850 *cubic feet per minute.* This is corroborated by a trial of its velocity in the main air course below, which gives for those 400 acres 29,250 cubic feet per minute. The slight discrepancy of these two volumes may be accounted for by the rate of the shaft column being taken when the corves were out of it, and the main air course when they were passing and the *pit at work.* There is in the C Pit at Wallsend a reduction of nearly $\frac{1}{7}$th of the supply in its 8ft. 9in. diameter by the working of the corf, which corroborates the foregoing conclusions.

Rate of current 1$\frac{1}{10}$th foot per second.

This column of air, of 29,250 cubic feet per minute, supplies this mine of about 30 millions cubic feet of excavated passages, which, if it travelled the entire course without being divided, would at that rate take 16 hours at least to travel through the whole mine, accumulating gas as it advanced. But the air is split, as it is called, into two great columns, ⅔rds going to a more distant working, and ⅓rd clearing the passages in another direction. The whole column of air, before it splits, after it first leaves the downcast, moves with a velocity of about 435 feet per minute in an area of 64½ feet; but ⅓rd of this air being separated for a western section of the mine, the $\frac{2}{3}$rds is then carried down to the principal and most extensive workings, leaving for it about 19,500 cubic feet. This air, losing $\frac{1}{3}$rd of its volume in the same area, is decreased in velocity to nearly 300 feet per minute; but as it passes into the *sheths, panels,* or divisions of the workings, and is coursed up and down the boards, it is split into three distinct columns, each of 90 feet area, and there *creeps sluggishly through them at a rate of about 66 feet per minute, or* $1\frac{1}{10}$*th feet per second through* $\frac{5}{7}$*ths of the entire mine.*

With such ventilation, explosions unavoidable.

When we have observed, as at the beginning of this report, that the carburetted hydrogen is so abundant as in one instance to surcharge an atmosphere at a rate of more than 4,000 cubic feet per minute; in another about 1,799; and from a small goaf of 5 acres, a supply of 52 cubic feet of pure gas per minute; it may be fairly predicated if no more or better ventilation exists in the two former instances than in the case just detailed, or if this had so large a discharge of gas, that they must all frequently be on the very verge of explosion, especially in some stagnant recess of the mine of 70 miles extent of galleries. When to this it is considered that these explosions are *always from a very limited portion of the mine,* as at Wallsend, St. Hilda, Willington, &c., and that the air dwindles to a state of almost imperceptible motion, as we have seen, of not more than $1\frac{1}{10}$th foot, or $\frac{3}{4}$ths of a mile per hour in the greatest part of the mine, it is matter of surprise that these lamentable occurrences, instead of being occasional are not incessant and overwhelming. Living thus always on the verge of destruction it has excited amongst the officers and men of mines a continual watchfulness and knowledge of dangerous symptoms that alone enable them to proceed with any degree of safety in such a situation; but in which on the smallest error, or a contingency unforseen or incapable of being prevented—as a boy asleep or at play—a heated lamp—a broken wire—a sudden eruption of gas, or a change in the wind and pressure of the atmosphere—and the bounds of safety can no longer be preserved; but tremblingly alive to their danger, as at Wallsend, they are plunged unresisting victims into the abyss.

The fault is in the system, not in the officers and men. The Committee have seen the most incessant care and watchfulness amongst them in almost every instance: such as the loss of life (their own amongst the number) and serious destruction of property, may be supposed always to induce. But the Committee are perfectly convinced that with such a small force of ventilation as can be obtained by the present plan, and as in the north is commonly pursued—which the instance just detailed demonstrates—no human foresight or skill in its application can obviate these explosions. While this imperfect ventilation is allowed to continue, *the mining districts and the public must prepare themselves for the continual recurrence of these dreadful calamities.*

Example Second is a pit 14 feet diameter, for all purposes of ventilation, drawing coals, &c., to a mine of even more extensive subterraneous workings than the last, some of them beneath the Tyne into an adjoining county, and upwards of 1,000 feet below the surface.

This pit, deducting area of brattices, about	15	feet.
And corves, when working, 2 areas	17	„
153.9384—	32	

Will leave about 122 feet area for shafts to this tremendous subterraneous excavation.

Second Example: current 1 foot per second.

The consequence was, when the Committee tried the air in the main courses after it had been divided into its great trunks:—In the north way, with an area of 65 feet, they found its rate under 3 feet per second; in the west way, area 60 feet, $5\frac{1}{2}$ feet per second; and in the south, area 60 feet, $3\frac{1}{10}$th feet per second. This again, when *split* in the boards each 90 feet area, and coursed down and up two, *without taking into account the immense waste from imperfect brattices, would leave the almost imperceptible motion of little more than* 1 *foot per second, or about* $\frac{2}{3}$*rds of a mile per hour; and from the west* *way, at the most,* 1·8 *foot, or* $1\frac{1}{4}$ *miles the hour. Thus reducing the general ventilation considerably lower than* $\frac{1}{2}$ *of that stated in the evidence* of Messrs. Buddle & Wood. The able viewer of this pit, by a *judicious* mode of *splitting his air, and pouring it directly on the distant faces of his work, and where his men are employed* makes the best possible use of his very limited means of safety. That the air thus struggling through these extended passages, where oozes gas at every pore, at a rate of 30 cubic feet per second, should become surcharged and explosive, is a physical consequence as clear as a mathematical demonstration. In such a system there is every thing to encourage the production of an explosive mixture—just sufficient air to prepare, in some neglected recess, the combustible: not enough to dilute or sweep it away. Perpetually ready, on the slightest derangement of any of its machinery, it falls naturally at once into a vast arena of subterraneous thunder, whose terrors a boy's finger can unloose.

Example Third: one ventilating furnace for 4 mines.

Example Third is a colliery with 4 mines, having a detached upcast for the whole of 8 feet diameter. These 4 mines, as in a colliery already described, are superjacent strata of coal, which are ventilated by one furnace placed in the deepest seam, upwards of 700 feet from the surface. In the furnace drift, of about 45 feet area, the air travels only about 4·3 feet per second, passing about 11,610 cubic feet per minute from that mine, which by its greatest depth, and possessing the furnace, should enjoy the fullest circulation. This is corroborated by the *entire upcast of the* 4 *mines,* which is about $50\frac{1}{4}$ feet area, passing the expanded air at the time of the Committee's visit, at the rate of 50,064 cubic feet per minute. In one of the leading air passages, of 28 feet area, they found the current about 6 feet per second, supplying 10,080 cubic feet per minute, which, on being coursed in the usual way *in the boards, would not allow a rate of* 1 *foot per second, or* $\frac{2}{3}$*rds of a mile per hour, and which in the upper mines would, as a matter of course, be much reduced below that very small rate, rather yielding a draining or scaling of air than a free current of circulation.* A dangerous condition of ventilation, which, but for a careful and steady attention to the mine, aided by their very short courses, none of which extend much over two miles, would easily lead to very serious results, and might at any time set at defiance their ablest calculations and arrangements.

Ventilation of a goaf.

In one of these mines the Committee observed *a goaf ventilated,* though, of course, from its nature but imperfectly. A pressure of air was kept upon one side of this walled-up reservoir of gas with apertures for the admission of the air, and in the opposite side similar passages for its exit into the return current; this perpetual flow of air through it and amongst its broken and confused masses tended very considerably to prevent the accumulation and dangerous encroachment of the gas. The air as it entered was 63° Fahrenheit, and on its exit with the gas 64°.

This plan of pressing the air upon goaves is generally pursued when working in their vicinity, which is, of course, done to windward, and commonly with lamps; but it was so well arranged in this instance that the flame of the lamp gave clear indications of a fair steady current, not too often found in such situations. This mine, with its low state of ventilation, is considered in a good workable condition, not inferior to, or more dangerous than any other colliery of the northern district.

Example Fourth: current ·66 feet per second.

Example Fourth is a mine upwards of 1,580 feet beneath the surface, with a single shaft for its ventilation. The Committee found the air travelling in this pit, in the chief air passage, at 7 feet per second in an area of 36 feet, giving 252 *cubic feet per second;* and the *return* air, in a passage of 30 feet area, travelling at the same rate of 7 feet per second, having, running parallel to it, a *passage of* 18 *feet area through which part of the returns crept at the rate* .66*th of a foot per second, or much under* $\frac{1}{2}$ *mile per hour. A very good rate for preparing an explosive mixture had there been an ordinary disengagement of gas, which from some peculiarity was fortunately far from abundant.* Whether this was caused by the depth of the mine producing a temperature seldom below 80° Fahrenheit, conjoined with great displacement and confusion in the strata, which may have effected early evolutions of gas and prevented its accumulation in large quantities by the frequent faults dividing these strata into small impervious enclosures, and so affording, on opening the mine, easy and natural facilities in the heat and disruptions for its escape, or whether from some other cause it is perhaps difficult to say. The fact is, however, indubitable, and fortunate it is that it is so; for had the gas been in the same abundance, as in some of the mines already instanced, the very trifling volume of air passed into this mine, *on the usual principles of dilution acted on, would, if not improved, in a short time have compelled its relinquishment, by the production of a series of explosions which would have laid it waste, and deterred the boldest from entering it:* for the only and certain effect of such admixture of air would have been the production of an explosive compound, which, like a slumbering evil spirit, would have swollen in every vein of the mine, concentrated in strength by the increased pressure of the atmosphere from its depth, that neither safety-lamp, candle, nor furnace, could have touched without awaking its terrible power. Less dangerous would it be if the supply of air was reduced to the minimum proportion, with more than ¼th or 25 per cent. of gas, which would place it above the explosive point; for such imperfect ventilation as that only affords the food that gives life to the dangerous preparation.

The following is an extract from the minutes of a visit by the Committee to *another extensive colliery*, that were written at the time. It displays the daily condition of the mine; which is so much in accordance with the usual principles of operation in the great coal district, that no means are taken to produce a change:—

A mine all pillar-working: imperceptible ventilation.

"The depth to the '*high main*' is about 600 feet. This mine has two distinct pits—a downcast, about 11 feet diameter, and upcast, 8 feet diameter—placed from each other, distant on the surface about 200 yards. Near the bottom of the downcast, *within a few yards, found a lamp-room*, beyond which no one was allowed to pass with a naked light (all Davy lamps), for which there is great necessity, as in the 'high main' it is now *all pillar-working, with goaves all around, right and left.* We went straight to the working parties, at a considerable distance, (passed in our course through a whinstone dyke running nearly east and west, about 15 fathoms thick,) *the passage to which had a small velocity of air:* the rate of which could not, of course, be tried in this mine in the usual way, as neither explosion of gunpowder, nor measure by candle, could be attempted in its surcharged atmosphere; *but the air scarcely bent the flame of the lamp from its perpendicular, or was perceptible to the senses.* It *scaled off* (the deputy stated) into the *imperfectly stopped goaves on one side of the passage; the goaves on the other side being more carefully stopped.* The object was to get *a pressure of air upon the goaves from the men,* that the gas might be kept in its reservoirs or gently expelled into the *returns* on the other side of the goaves. * * * * But the day before, from negligence of some party to a door which had been left open, *such current as there was* had been diverted into another direction, and the consequence was, *that that very morning the workings then visited had been fouled; the gas having come off the goaves backward. It was, however, observed, the workmen were kept back till the current was set right, and the furnace increased for a stronger ventilation;* when this insidious foe returned to its lurking place, and the men were then going on as usual."

Insufficiency of the ventilation.

It is unnecessary to accumulate statements of more proofs: nothing can more clearly shew than the instances just adduced, the insufficiency of the practice, mode, and extent of the general system of ventilation pursued in the northern mines, although occasionally, as at Wallsend, it may be more skilfully applied.[i] Had there been a more perfect and fuller system in operation in any, humanity and interest, to say nothing of public opinion, would have influenced its adoption in these. Or, the workmen, amongst whom at the present day are men of intelligence, would, in self-preservation, have compelled the improvement, or sought for such security in safer mines.

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[i] Wallsend possesses at this time about 75,000 cubic feet of air per minute for about 130 acres excavation, through three shafts: one 8 feet 9 inches, and two each 6 feet diameter, the whole being unequal in area to a 14 feet pit. In the main air course of the chief pit, 64 feet area, the air travels at the rate of 10·9 feet per second, and no course is longer than 4 miles; notwithstanding, in the boards, the rate will be found below the amount stated by Messrs. Buddle & Wood.

An imperative necessity for a change.

The Committee are therefore obliged, from a strong sense of public duty, to record their conviction, derived from personal inspection of many mines, and the fullest official information of many others, *that the system and rate of ventilation of the mines in this extensive Coal District require a great and important change;* for, if allowed to continue, there is scarce a single mine amongst them, with one or two rare exceptions, that in a day or hour may not be plunged by some easy contingency into a destructive explosion: and that *this state of things is produced by too few shafts to the extent of underground workings, and the consequent slow rate of air which is produced to sweep the passages, rapidly to remove or fully to dilute the gas.*

More Shafts and more Air.

More shafts and more air.

More shafts and more air are the only certain remedy, the Committee are persuaded, for this unsafe condition of these mines. This opinion is sustained by practical men, some of them of great eminence.

Smith.

R. Smith, Esq., a mining engineer, employed extensively in the Staffordshire mines, and formerly in those of Portugal, and who brought into operation the dangerous mines of Nova Scotia and Cape Breton, states, on his examination by the Committee of the House of Commons to question 3,852:—" Did anything occur to you as a practical man on hearing these examinations, with respect to the danger so imminently incurred by the miners of that district?" (the Northumberland and Durham.) " *There did.* It must be what occurred to me on hearing the examinations, for I have never been in that district; *it did appear to me when I saw the plan which Mr. Buddle exhibited, that their works were carried to an extent beyond the safety of ventilation,* considering the high percentage of gas they were represented to produce. I have no wish whatever to interfere with other people's concerns, except so far as relates to the safety of miners; and if I saw anything wrong in that respect, I think I should not discharge my duty and my conscience unless I tried to remove it."

He always relied on ventilation alone.

3854.—" You said in the very dangerous works you superintended in North America, *you relied entirely on ventilation? Yes, always, wherever I went;* I think I should not be doing justice to the miners under my care, if I left them entirely exposed to the use of an implement (the safety lamp), which, itself being liable to accident, might destroy the whole of them. If there had been such an explosion in the coal mines in Nova Scotia as there was in the north of England the other day (at Wallsend), it would have swept away the entire establishment of the company." * * * And " when I saw the plan produced by Mr. Buddle, but which I had not an opportunity of examining carefully, nor except when under examination by different gentlemen, *I was surprised to see the extent at which those mines were opened compared with the limited means of ventilation in the shaft.*"

Thus speaks Mr. Smith of about one of the best ventilated mines in the north, with 4 distinct pits for 130 acres: what would have been his surprise to have examined their average condition, or to have seen *one shaft for* 3, 4, 5, *and* 600 *acres and upwards.*

In Staffordshire: 1 shaft to 16 acres.

In Staffordshire " *they never like to take their pits more than about* 300 *yards from each other.*" *Each* is supposed to *get from* 15 *to* 16 *acres of coal.*[j] The average depth is about 450 feet. This gentleman has been fortunate enough never to lose any lives by explosion in the mines he has managed. He adds,[k]—" *The true principle* of working mines will be that of *efficient ventilation;* and my opinion is, that you never can work coal seams any other way so *properly and profitably as by keeping the men always in a safe and healthy atmosphere.*"

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[j] Parliamentary Evidence, 3,027—3,123. [k] 3,189.

Walker.

C. J. S. Walker, Esq., a colliery proprietor, near Manchester, gives this opinion :—" I believe from what I have heard and what I have seen, that the *best method* is by keeping up *a proper ventilation for preventing these accidents*."[l]

Mitcheson.

Mr. George Mitcheson, a mine agent in Staffordshire, states, that ventilation, even by the workmen, is considered so important that they " are always under the necessity of putting their mines in a good state of ventilation before they (the men) will go to work again after an explosion."[m]

Wood.

Mr. Nicholas Wood, of Killingworth, considers ventilation " *of the very greatest importance ; to produce a good current is of the very greatest importance*."[n]

Elliot.

Ralph Elliot, of Pensher, says :—" I would make free just to name *one thing*, which might be of *some importance in the prevention of accidents in coal mines*. I think, if public attention was more particularly called to the subject, and *something done to get the best system of ventilation made known to the country ; something of the kind, it is my opinion, would be of service*."[o]

In the *metallic mines of Cornwall*, in which they have no explosive or deleterious gas to encounter, and the depth of which are not inferior to the coal mines of the north, one of them being upwards of 1,500 feet deep, and on an average they are not less than 600 feet, yet they sink shafts every 2 or 300 yards for the purpose of ventilation.

Taylor :—Proportion of shafts to galleries in Cornwall.

John Taylor, Esq., a civil engineer, entirely connected with mining, states (Minutes of Evidence, 133) :—" I am sorry I cannot state to the Committee the number of shafts at the consolidated mines (in Cornwall), but I think they extend. including the winges (the staples), *to more than 12 miles of perpendicular depth, and I believe the horizontal galleries to more than* 40." To a coal mine in the north, with galleries to nearly *double* the same extent, they have *a single shaft, or scarcely* ⅔rds OF A MILE *in perpendicular depth.*

Mr. Taylor is asked (136)—" But as intimately connected with mining, cannot you suppose a case in which a considerable period must elapse after the completing of one shaft before it becomes expedient on the part of the owner to sink a second ?" His answer is " certainly ; but we consider it the great duty of the directors of mines to *foresee all such circumstances ; and we consider it the worst management possible to delay the sinking of shafts to a period that would become inconvenient.* I look upon that kind of foresight to be the great improvement in modern mining.

137.—" That is according to modern practice you would avail yourselves of the shafts hereafter expected to be wanted for the purpose of immediate ventilation ?—*Certainly*."

140.—" Then by immediately *working up to a certain extent on your ulterior plan you obviate the neceessity of perfecting the ventilation at one shaft ?—Yes*."

On the introduction of the Davy lamp, Mr. Taylor doubted its nature, because he feared " that it would tend to make the owners of collieries *not* take *the same pains for ventilation* that they otherwise would do : my opinion being, that the only safe thing for collieries is to get rid of the gas if possible."

He concludes (280) :—" Without presuming to know so much of collieries as to dictate to those that manage them, I have always thought it desirable *to try a more perfect ventilation of collieries, either by introducing a system of more numerous shafts, or by some mechanical power*."

Garforth.—Shafts in Lancashire, and cost.

John Garforth, Esq., a proprietor and director of mines in Lancashire, is asked, amongst other things, by the Commons' Committee (3,646) :—" Do

[l] Parliamentary Evidence, 4,180. [m] 2,574. [n] 922. [o] 766.

not you think it would be an act of kindness to enforce the constant use of the lamps in your mine ?—*I think there is a better way.*" He replies, * * * "*Sink more shafts : there will nothing else do.* I have been acquainted with it all my life, from 10 years old, and I am now approaching 70." And that is the conviction of his lengthened experience—"*Sink more shafts.*"

He says, in another place (3,747) :—"*Only sink pits enough, and it will be preferable to all lamps.*"

He is asked :—"*Would not the frequent sinking of shafts render the expence of working the colliery much greater ?*" "I think (he answers) they would save it by the lamps." 3,751.—How ? "*They would get more coals for the same money.*" 3,752.—Do you mean that by bringing the coals a shorter distance *they would raise them so much cheaper as to pay for the extra expence of sinking so many shafts ?*—"*That is my opinion.*"

The depth of their shafts are from 750 to 1,000 feet; and the diameter from 10 feet 6 inches to 11 feet 6 inches: and they have quicksands and feeders of water to contend with. Yet to sink a shaft 11 *feet diameter for about 250 yards, would cost there, when walled with brick and lime, about £5 a yard.* This is a very frequent depth and condition of the northern mines, where owners are deterred, it is professed, from sinking sufficient shafts, by the enormous expense of sinking and securing.

The eminent engineer, *George Stephenson, Esq.*, says to the same Committee, "*the ventilation in collieries is certainly very faulty.*"[p]

Want of ventilation, alone the cause of explosion.

This Committee feel satisfied that there remains now not a shadow of doubt, of the northern coal mines, owing their dangerous condition to the want of ventilation, and to that alone. But their exists from this imperfection of their ventilating arrangements, other mischiefs of a destructive nature. In a mine limited to one or two shafts, these shafts are obliged to be divided into two or three, sometimes four compartments, by partitions of wood called *brattices*, for the purpose of having at least one ascending and one descending column of air—the upcast and downcast, and a division for the pump, &c. The consequence is, that the woodwork is perpetually getting worn and deranged, when the air rushes, from difference of temperature, through every crevice from the downcast to the upcast, wasting, in their limited ventilation, the stream at its source. And from its weak construction, in case of explosion, the lower part of this brattice is sometimes blown down, thus entirely arresting the ventilation of the mine which, would not have occurred had there been two or three separate pits. This took place at Killingworth in 1806, and for want of ventilation it was 23 or 24 weeks before they could reach the bottom of the shafts ; and on the explosion at Wallsend in 1835, about 30 fathoms of the brattice were blown down, by which, out of the 102 lives lost, Mr. Buddle thinks 40 to 50 were destroyed that might have been saved.

Bratticed shafts, and their bad consequences.

These divisions of shafts are most expensive to keep in repair : they have been known, in some shafts, to cost £1,500 a year.[q] Water in the upcast is obliged to be kept running down the brattice opposite the furnace drift to prevent its taking fire, which being kept moist at a high temperature speedily decays ; and, in some instances, the pit is obliged to be laid off and the furnace put out *every fortnight* for the workmen to go into the shaft to make repairs.

The expence in labour, wood, ropes, and time, the Committee believe, would, after a few years, fully compensate for additional shafts ; when the facilities of working and drawing the coal, and ventilating the mine, are, in addition, taken into account.

Letter from George Stephenson, Esq.

Mr. George Stephenson, in a communication to this Committee, expresses decidedly the same opinion ; a large extract, from which is here given, as it contains his matured and experienced conviction on that and one or two other points :—

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[p] Parliamentary Evidence, 1,562.

[q] Parliamentary Evidence, 2,127.

"It would give me the greatest pleasure, he says, if I could throw out any hints to you, whereby the accidents that are frequently occurring in coal mines could be prevented.

"The workings underground of a large colliery are so complicated that it is a difficult task to improve the mode of ventilation:[r] there is always a number of doors required in a large mine, and any one of these doors being left open, *by a boy falling asleep*,[s] may cause some part of the mine to become charged with hydrogen gas, and an explosion from that district may follow, *although the safety-lamp be in use, they may not always be in a perfect state.* There ought to be a person who thoroughly understands the lamps, to have a cabin or house a certain distance from the downcast shaft, and in a situation where the current of atmospheric air is so strong that no danger can be apprehended in that quarter. No lamp ought to be made use of which has not passed through this man's hands.[t] *But after all this precaution a lamp may become fractured by a blow, and in a situation where the ventilation is not perfect.*

"*Great care should be taken always to have a double current for the air-course in the old workings*, as falls are frequently taking place, obstructing the passage of the air; indeed, I have known defects frequently take place from the cause here stated.

His objection to bratticed shafts.

"*I think the ventilation of coal mines would be much more certain if two pits were sunk instead of one; the system in the neighbourhood of Newcastle has been to sink one large shaft, and to divide it into two, three, or four divisions, between the one and the other being only five inches of wood.* The air for ventilating the mine descends on one side, and after passing through the workings ascends up the other; the partition is frequently wearing out of order, and the air oozes through from the downcast to the upcast, there being a difference in the weight of the atmosphere in the one shaft and the other, arising to the one being heated by the furnace, while the other is not; and whatever air passes from the downcast to the upcast through the partition will diminish the quantity passing through the workings.

"*Now I consider that a much better, and, in the end, much cheaper ventilation, would be carried on by having two pits instead of one.* The Killingworth pit was 14 feet diameter, divided into four shafts by wooden partitions, as above described. Now *four seven-feet shafts* yield the same cubic contents as the one 14 feet.[u] It is true that the dressing of the sides in walling in the small shaft is double that of the 14; but, then, *all the wooden partitions are saved, which will make up the difference of the cost. By this plan only one rope would be required in each shaft, and the whole carried on with less wear-and-tear, and much safer for the men ascending and descending, and the ventilation up and down the shaft always perfect.*

His plans in Leicestershire, Derbyshire, and Lancashire.

"I have opened out a large colliery in Leicestershire on this plan; *shafts two hundred and twenty-two yards deep, and perhaps fewer accidents for the work done than any colliery in existence.* I am likewise opening out some in Derbyshire on the same plan, and *likely to be as extensive as any on the Tyne or Wear*, and the coal highly charged with fire-damp. I have adopted the same principle in Lancashire, *where the pits will be upwards 500 yards deep; and from all my experience I am satisfied that it will be cheaper in the end than sinking the large shaft.*

Accidents generally from faults in ventilation.

"It has frequently been proposed by people unacquainted with mining, to carry air into the workings by means of pipes, and also to get the *fire-damp* out by the same means: such a scheme can only be proposed from ignorance. *Archways may in many cases be applied instead of doors in the*

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[r] This remark refers only to the extensive underground workings on the present system, where a complicated series of passages, stoppings, doors, and brattices, is required to force the air round the whole mine. More numerous pits, or greater force of air, would remove considerably the difficulty and the risk, as is being shown.

[s] This is a proof of the necessity of not employing boys for that purpose, of 6, 7, 8, 9, and 10 years, as too commonly done.

[t] Such an arrangement in fiery mines is already very generally in existence.

[u] Each seven-feet pit area being 38·4846 feet, will give for the four—153·9384, the area of the 14 feet pit.

working—that is, one current of air being carried over the back of the other. There are always people employed underground, called wastemen, to look after the air currents : *the work that these men have to do cannot be overlooked by a superior ; and these men, if not honest in doing their duty, may lie down and sleep instead of working, and the air-course is then neglected.* Now if a plan can be laid down to have a commission formed by the various coal-owners to look after the men occasionally, by examining the whole of the air-course under their charge; and if any part of the mine should not give a certain number of cubic feet, some punishment to be put upon the wastemen for such neglect.[v] I am quite aware there will be some difficulty in making such arrangements, yet I think it might be done. The quantity of cubic feet of area required for any mine can be found ; *and, generally speaking, there has been some fault in the ventilation of the mine when accidents have occurred.*

An Act of Parliament to regulate ventilation.

"*All doors ought to be hung that they will not remain open unless kept so by force. It does appear to me that an act of parliament might be obtained to have power to cause certain regulations to be attended to in the ventilation of mines.* There will, however, be some difficulty in obtaining the act, as there are so many conflicting opinions respecting the working of mines. I am myself very deeply concerned in coal mines, and shall be ready at all times to render you any assistance in my power."

It will be observed that Mr. Stephenson's communication enforces strongly the necessity of having distinct and separate shafts, both from ultimate cheapness and indubitable superior advantages. Indeed, were the cost greater than it is, the absolute necessity of an entire change in the present practice on this point is urgent and unavoidable. The Committee are so satisfied of its future adoption, that they feel assured no *new* mining operation will be attempted without having recourse to distinct ventilating shafts, discarding the old-fashioned, unscientific, and dangerous *single-pit for ever.*

Errors of the Commons' Committee of 1835 on the cost of shaft sinking.

This Committee have observed with regret that the Commons' Committee of 1835 had been erroneously impressed, and endeavoured to extend that impression, that the enormous cost of sinking a single shaft precluded the possibility of attempting a second for the same colliery; that no proprietors, considering the nature of the speculation and profits, would be induced to advance so large a capital as would in such case be required, and that consequently should such a system be brought into operation, a number of valuable collieries would thereby be thrown out of existence.

When Mr. Taylor is recommending to that Committee (280) more numerous shafts for ventilation, they asked him "if he was aware that the *cost of sinking a single shaft* would frequently, in the counties of Durham and Cumberland, *exceed* £100,000?"[w] and when Mr. Garforth, of Lancashire, is telling them that though they have there feeders of water and quicksands to contend with, yet they can sink a shaft of 11 feet diameter 250 yards, and properly walled, for £1200 to £1500, a little more than £5 a yard, they astonish him by stating, "*that in many districts of the north a shaft of the same diameter, and to the same depth, would cost* £50,000."[x]

These assertions of that Committee are entirely unsupported by the facts of the case, and seem to be an extraordinary exception or two (such as Monkwearmouth, said to have cost £80,000), which they have entertained as the ordinary scale of sinking, instead of the usual and average cost of such an operation. Mr. Buddle himself, in describing an instance *of the worst description*, and reasoning against the sinking of more capital in the same mine by more shafts, admits, that he cannot give the Committee an idea of the expense of sinking *difficult shafts*, but "*he believes there are some that have cost* £40,000 and upwards to reach the coal."[y] Now Mr. Buddle, with his very extensive experience in every description of mine—and a man of his eminence would be certain to be consulted in almost every *difficult* case—cannot affirm that he KNOWS of any Shaft that has cost £40,000; but "HE BELIEVES THERE ARE SOME." Although a gentleman experienced in all the difficulties of his profession, and a coalowner himself, he knows no case where a shaft cost that amount; yet the Commons' Committee impress upon their evidence that there are some cost £50,000, and in several cases exceed £100,000. On this point of such vast importance to the mines, it is deeply to be regretted that the Committee had not instituted a series of inquiries that would have elicited correctly the exact expense of shafts of different depths and diameters in various localities in the several mining districts. They would thus have produced most valuable information for the future safety of mines, as well as their economical working, and, this Committee feel assured, would have placed the above extraordinary sums in very striking contrast with the real amounts of cost.

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[v] This seems to be more peculiarly the duty of the viewer and officers of each particular mine, and not of a general commission. Although these wastemen are not conveniently to be followed in their daily course through the old passages, yet it is the bounden duty of a superior officer frequently and unexpectedly to appear amid the scene of their operations, when so much depends upon their honest performance, and to demand a daily account of their proceedings. He has also a check in the mine itself when obstructions take place in ventilating passages to any extent; the pressure and gorging of the other passages make the wind whistle and sound more loudly through the doors and crevices, which intimate danger by "*calling.*"

[w] Parliamentary Evidence, 281 and 2.

[x] Idem., 3,755, 6, and 7.

Average cost of shafts.

From the best information which this Committee has been able to obtain, shafts can be sunk even in this *difficult Coal District*, ON A REGULAR AVERAGE, *at least from* 70 *to* 80 *per cent. less than stated by the Commons' Committee:* the mere sinking of the shaft and walling not amounting to much more than stated for Lancashire. A single 11 feet pit, down for 300 yards, would not cost more, under ordinary circumstances, than £2,000 to £2,300:—nor would a 14 feet pit, for the same depth, require a greater sum than from £2,500 to £3,000. But as both for reducing such *feeders* of water (some of them 1,000 gallons a minute, or, as at Haswell, upwards of 26,000 tons a day,) which are probably to be met with in the shaft, generally from 30 to 70 fathoms down, till the tubbing or caissons are fixed, and also for keeping the mine afterwards clear, a large pumping engine of from 200 to 300 horse-power, is generally required:—For example, if of 250, there will be an additional expense of about £5,500 for an engine with its masonry, &c., but which is as much for the mine as the shaft, and only one generally, besides winding engines, for the sinking of two or more shafts, need be erected on a single colliery.

The Committee have data before them shewing the expense of sinking some ventilating and winding shafts 8 feet diameter, nearly 200 yards down, that did not amount to £3 per yard for sinking and walling; and one 11 feet engine pit that cost less than £5 per yard. These shafts were lately sunk in this district, and there was only one 250 horse engine at the largest. On the same system, two shafts at least may be invariably put down under the operation of one pumping engine, absolutely necessary to be afterwards employed. After one shaft is sunk, or when it is being in progress, without there be some extraordinary and unusual quicksand or feeder of water, a second is put down much more easily, as the first serves to drain and keep the other dry, if placed within a reasonable distance. As a proof of a better light dawning on this point, the Committee have the satisfaction of observing that two 14 feet shafts for one mine, are progressing simultaneously in a *difficult district,* though they will have to be sunk nearly 400 yards, before reaching coal.

Datton-le-Dale shafts and engines.

A solitary instance at Datton-le-Dale, in the Durham district, of an almost impassable quicksand, which required many months' exertions, and a power of engines of 1,274 horses, never before employed at a colliery, must not be taken as a rule, but another striking exception to the facility of such operations. Yet even in this extreme case, so satisfied are the intelligent owners and viewer of the necessity of abundance of shafts, that, though they have two 14 feet pits within 45 yards of each other, they are expending this immense labour and cost to add another of 16 feet diameter within a 55 yards' range of them. Perhaps had they planted this pit at the limits of their intended ventilation, if not to be used chiefly as an engine pit, it might, in addition to avoiding the quicksand, have been more advantageous as an upcast, saving the waste of a return current and the friction of half its extent.

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[y] Parliamentary Evidence, 2,150.

The average rate, which should rule, is such as has been stated: and when it is considered that the repairs of a bratticed shaft not unfrequently amount to from £1,200 to £1,500 annually, and that the cost of one or two small ventilating shafts, of 6 or 8 feet diameter, will, in most instances, amount each to little more, it surely is both consistent with humanity and economy invariably to adopt them.

Number of acres to a shaft.

It is difficult to form an exact opinion as to the number of shafts required for an extensive mine, which vary somewhat according to circumstance; but considering that in the metallic mines of Cornwall, as deep as the coal mines of the north, for the sake of healthy ventilation alone, they have shafts not more than 300 yards from each other:—that in Staffordshire, where gas and danger are not so abundant from their average depth being about 75 fathoms, they generally have their shafts for the same purpose not further apart than 300 yards, which ventilate not more than 15 to 16 acres each:—that in Lancashire, they almost never sink less than two or three shafts together; and that Mr. Buddle, the great improver of ventilation in the north, has for Wallsend, 140 fathoms down, 4 shafts for about 130 acres, two of them 6 feet diameter; it appears reasonable to conclude, that *in no case ought there to be less than one ventilating shaft, however small in diameter, apportioned to, at the least, every* 40 *acres;* and that no "*winning*" should be allowed to be made, UNLESS TWO DISTINCT SHAFTS HAVE BEEN PREVIOUSLY PUT DOWN, which should be secured by Act of Parliament.[z]

Proportionate area of downcasts and upcasts.

In the arrangement of the downcast and upcast shafts it is necessary to keep in view that the latter, in furnace ventilation, should always be at least as large as the former, because there is fully $\frac{1}{7}$th more expansion in it; taking the average difference of temperature in the two shafts at 70°, which is low. If as much as in some particular pits at certain periods, the proportion would be still greater. The unfortunate error exists of almost invariably having the areas of the downcasts greater than those of the upcasts, sometimes in a proportion of nearly 2 to 1, it not being observed that the expansion by heat, after combustion of the products of the air, the nitrogen and carbonic acid gases, acts directly as an obstruction, and consequently reduces the admittance of air through the downcast by that amount, which is only partially relieved by the increased velocity of the upcast. Mr. N. Wood "thinks the area of the upcast pit ought to be larger than that of the downcast pit." Mr. Smith is also of the same opinion; or the velocity must be greatly increased to remedy the defect.[a]

Even with the more abundant sources of ventilation, above detailed, it is necessary not to neglect the improved advantages which modern science offers to set in motion the columns of air that present themselves in these shafts. If the current be still allowed to creep sluggishly through an 8 or 10 miles' course, at a rate, in many parts of not more than 1 foot per second, no great advantages will be derived from the proposed change. For if a mine discharges Gas at the rate shown at the commencement of this report, or approximates even distantly to the proportion as instanced from 5 acres, there will be produced an enormous body of gas in the 24 hours, which ought to be diluted and swept away, not by the dangerous proportion of 25 or 30 times its own bulk of air, but by a quantity infinitely further removed from the chance of accident.

HIGH-PRESSURE STEAM VENTILATION.

Gurney on high-pressure steam ventilation.

An admirable suggestion for the procuring an increased force of ventilation has been made by the discoverer of the Bude Light—the scientific and ingenious Gurney. It is the application of *high-pressure steam*, which the more the Committee have examined has grown the more valuable in their opinion; they now feel assured it is fully adequate to every condition of the mine, and will produce with more certainty and safety an increased rate of ventilation than can be effected by any other means.

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[z] George Stephenson, Esq., conceives Ventilation is a clear subject of arithmetical calculation. He thinks "if a certain current *could be by law* forced up to the neighbourhood of the mine in a certain area of space it would be a great certainty as to preventing explosions: he does not know whether such a law could be carried into execution." When asked if there is a total ignorance of any theory as to the required extent and nature of the supply of air, in answer, "he believes quite so."—Parl. Evid. 1802 and 3. He also thinks a code of laws might be established to prevent accidents in mines, though he could not give a decided answer.—Parl. Evid. 1813 and 14.

[a] Parliamentary Evidence, 924—3859.

Mr. Gurney first made the suggestion before the Parliamentary Committee in 1835, and since the organization of the South Shields Committee, at their request, he has more fully detailed, in several communications, the power, safety, cheapness, and facility of its application. The matter seems so important in the eyes of the Committee that they give these valuable documents almost entire:—

"Bude, September 27, 1839.

"Sir,—

"I have been absent on the Continent for the last six weeks, and your letter addressed to me in London respecting Fire Damp was sent with others to this place to await my return. I beg to answer it now, though I fear too late for your views. Since I gave evidence before the Committee of the House of Commons in 1835, I have had occasion to experiment extensively on the power and practical effect of ventilation by high pressure steam, and see no occasion to alter my opinion there given. In regard to lighting coal mines by reflected light; within certain range and favourable position I believe it practicable; in very extensive galleries it would be difficult, if not impossible, to do it from external sources of artificial light; but I conceive the new light which I have introduced at the light-houses, and which has been called the "*Bude Light*," may be insulated from danger in the galleries of mines; and from sources so insulated many mines may be lighted and worked with safety, using the luminaries as focal centres for paraholas or refractors, with the dioptric or catoptric systems, as circumstances render most available.—Any information I can give, I shall have much pleasure in communicating, &c. &c."

* * * * * * *

"London, October 29, 1839.

Sir,—

"In the downcast shaft, of 41 feet area a current of air of the rate of 20 miles per hour, must be effected to quadruple the quantity of air now passed through the mine by the furnace.[b] To do which I should recommend the high pressure steam to be applied in the upcast shaft, which I presume is about five feet six inches square. The power to produce the above current and corresponding velocity through the galleries, cannot be accurately determined unless the diameters, &c., were first ascertained, but for the end in view sufficiently so for practice.

"Sixteen jets, of $\frac{5}{16}$th area, fed by steam of 40lb. to the inch, placed not less than 30 feet deep in the upcast, and equally divided through its sectional area, would produce this rate of current through the downcast shaft. They should point perpendicularly upwards, and be supplied by one tube or steam pipe equal to the sum of the area of all, from a boiler placed in any convenient situation out of the mine. *The principle of ventilation by this means is positive, the only question is that of expense; and where coals are cheap, it possibly is the cheapest. There is no machinery to get out of order;* and as one or two spare boilers might always be fixed and ready, it seems to me as certain as any human means can accomplish. It need not interfere with the furnace ventilation, and as they would assist each other, the latter should be retained, in which case, if any thing occasioned the steam ventilation to stop—the furnace would go on. The boiler should not be less than 30 horse power. Some accuracy in adjustment and form of opening of jet is important to full effect, which I will communicate, or, if you desire to try the experiment, I will with great pleasure come down and give you all the practical information in my power."

"8th February, 1840.

Dear Sir,—

Description of apparatus.

"From the boiler A, Fig. 1, let a gas pipe, B B, one inch and quarter diameter, be carried down the upshaft to E: say 20 or 30 feet deep. The pipe, B B, must be made to connect with a series of pipes, c c, Fig. 2 (horizontal section at E), one of which is shewn A, C, in Fig. 1. Screwed into the series of pipes, small jets are to be placed about a foot distance from each other, as shewn at a, a, Fig. 1, and a, a, Fig. 2. A full size drawing of one of these jets is shewn Fig. 4: D, the branch tube; F, the jet tube, closed at the end H to $\frac{3}{16}$ths diameter.

"I have supposed the upcast to be about six feet square: the number of jets are proposed to be 25: this number will, I conceive, be sufficient to produce the rate of draft required; a larger number, however, would increase the draft current. If the shaft be round, the arrangements might be made as shewn at Fig. 3: *a cylindrical shaft is preferable to a square one.*

"You will observe from these rough drawings that very *small pipes* are required, which would be *easily and inexpensively fitted:* the rate of current of air produced will depend entirely on the pressure of steam, as it escapes at the orifices of the jets a a a. The pressure will be governed by the boiler, and regulated through the jets by the stop-cock K, Fig 1. * * * * You will observe that the apparatus is very simple, and not likely to become deranged, so as to interrupt ventilation: on experiment you will find the rate of current to be at command.

"I should much like to know the quantity of coals burnt to produce ventilation by the present mode;[c] judging from the effects and consumption in the House of Commons, where I had opportunities of measuring very accurately, and where ventilation is carried on by a fire in the upshaft, analogous to your ventilation in coal mines, *I should think the expense by the high pressure steam system would be considerably less than it now is.*"

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[b] This is in reference to a particular mine, the extent and area of its passages and rate of ventilation, having been given him.

"Argyle Street, February 12, 1840.

DEAR SIR,—

"In my last letter, I think I forgot in reference to the full size drawing, No. 4, after the words "reduced to $\frac{3}{16}$th," to add, capable of being worked to $\frac{5}{16}$ths; this applies to the size of the openings where the steam is to escape from the jets. On looking over your last letter I observe you described a mine of 35 miles' galleries, and only a 14 feet shaft; *in such a mine the steam blower, if applied, should be placed at the bottom*: thus at A, Fig. 5. It matters not where it is placed in practice, provided there be a *sufficient column of air above to keep the current uniform, and* 10 *or* 12 *feet are sufficient for this.* I stated 20 to 30 in the drawings, and that *because it is better to have more than less.* One observation more:—The application of the vis-a-tergo of steam is effective in the horizontal galleries or downwards in the descending shaft, therefore in some cases it may be more convenient to ventilate *by forcing air through the mine than by exhausting in the upshaft;* possibly in some cases a double action may be desirable. Air mixed with high-pressure steam (which it would be if the blower be placed in the down shaft,) might possibly be more agreeable to the men than without. Steam is perfectly dissolved in the current, and tends to warm it, and I believe is very healthy to breathe. I conceive you are now perfectly acquainted with the principle of Steam Ventilation, the practice you will, with your acuteness, see capable of much modification to suit circumstances," &c., &c.

Air may be forced through a mine.

The furnace drift the best situation for the steam ventilator.

The Committee, by their Secretary, pointed out to Mr. Gurney that fixing the steam blower with its jets in *either of the shafts*, while they were used *both as ventilating shafts and winding shafts*, or pits of extraction, as called by the French, would be impossible, for that large circular baskets, in most cases upwards of 3 feet diameter each, or iron tubs of nearly the same area, were perpetually passing up and down them, and that consequently some other arrangement would be necessary, and they suggested for that purpose the *Furnace Drift*, where, on the present system, the spring of the existing ventilation was placed.

The chief reasons assigned were:—That it would be more in accordance with the established usage of pitmen to have it so placed and that merely adding the boiler and pipes to the furnace, which would necessarily continue to exist for the production of the steam, a combination of rarefaction with a propelling power would be produced; and that should accident interrupt the operation of the steam-blower, the furnace movement, exactly as at present, would continue. By such an arrangement also in the furnace drift, devoted entirely to ventilation, the blower would be fixed in the most favourable position, and every particle of heat, both from steam and fire, directly employed, as well as the force of steam, in the production of the desired effect; and much of the steam that would have been condensed into water, by the colder air in the shaft, would then be thrown off in the furnace drift, free from the men and shaft operations, and which in its descent would have tended, in some degree, to retard the upward current. "The valve or door" which Mr. Gurney inquires about in his succeeding letter, is absolutely necessary, and is always in existence in the present mode of ventilation, so that there appears no obstacle to the easy adoption of the steam blower in the furnace drift.

No mechanical action to get interrupted or injured.

An objection is frequently made to mechanical means by some practical men, because it necessarily is liable to be injured and broken, and on such an occurrence would expose the whole mine to danger. But the combination suggested by the Committee would obviate entirely this difficulty, and there is no machinery here to break or get deranged. A strong boiler and pipes will not easily be affected, and when they get wrong, they can soon be repaired; or even at the worst, if the fire for one or two days is obliged to be put out, should they not have another boiler, as suggested by Mr. Gurney, they can only do as many of them now do for a day or two every fortnight when repairing brattices, put on a small water-power in the downcast from a pipe an inch or inch and half diameter, which will be quite sufficient for ventilation till all again is ready. The objection seems more tenable against a fan apparatus, air pumps, or other mechanical means in which machinery is in powerful and rapid motion, than *against steam ventilation with the furnace, in which no such action exists ;* and, indeed, to which it cannot in any manner fairly apply.

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[c] In a six-feet furnace about 1½ tons screened coals are used in 24 hours. In a seven-feet furnace nearly two tons coals, inclusive of about 18 cwt. *shaft*, or shakings from the corves in the shaft, in the same time. The latter sized furnace is commonly used as the only ventilating power in many extensive mines.

Mr. Gurney's answer to the communication alluded to above, is as follows:—

"Argyle Street, February 14, 1840.

"Dear Sir,—

The necessity of the ventilator affecting every part of the column.

"It would be more favourable if the steam jets could be arranged as shown in the drawing I sent you, but they will be sufficiently effective if the steam be passed through a less number, provided *each has sufficient power to start a column of air of a diameter that shall extend to and fall into the current produced by the next jet.* Therefore as three feet is required in the centre of the shaft for the corf to pass up and down, the number of jets must be reduced to 10. Fig. 6. *The sum of their areas* being *equal to* those of the larger number; it will require the steam to be kept a little higher. If the jets were placed in the diagonal opening, as shown in your sketch A, Fig. 7, the exhaustion B, would be almost wholly filled by a return current from C. At C the plus pressure takes place, consequently if there is a pressure from it to the expansion point (B) acted on by steam, it will return rapidly, and *a circle of air would only be moved at a great rate of succession. The same would happen in the upshaft, provided the influence of the jets did not affect every part of the column.* Thus a badly arranged blower, with a three feet opening, would affect the air in the shaft as shown by the arrows, Fig. 8 : *therefore it will be essential in practice to take care that the jets are so placed, and of a power sufficient to* MOVE THE WHOLE OF THE AIR *in the given direction.*

"If a valve or door could be placed at about D,[d] *the blower would act as well in the diagonal gallery as in the upshaft,* but this, I conceive, would be inconvenient, and not worth considering, as an arrangement similar to the one on the other side would be effective. A three feet basket takes up a greater part of the area of the shaft. Could this not be made, and be equally convenient in work, of a greater depth and less diameter?"

The Committee, previous to commencing their Report last year, again communicated with Mr. Gurney on one or two points, which are detailed very clearly in his reply, dated House of Commons, Dec. 3, 1841 :—

* * * * * * *

"I believe," he says, "*the cost* of ventilation by *high pressure steam will not exceed that of the rarified column* as produced *by the furnace* now in use for low velocities ; *for high velocities it stands alone and admits of no comparison.*

No limit to the velocity high-pressure steam can produce.

"Its great value for the purpose of ventilating coal mines consists in the fact *that there is no practical limit to the velocity of the current of air it is capable of producing* under proper arrangement, the cost of which I have reason to believe will be the quantity of the current multiplied by the squares of its velocity. In addition to the current of extreme velocity, *that of its being regulated at will,* and according to circumstances render it peculiarly applicable for the practical purposes of coal mine ventilation.

"When applied to produce exhaustion, I have in experiment carried it so far as to raise a column of water 4 feet high ; and when applied on the converse principle, I have produced a plenum which rose a column of water 5 feet, this was on a large scale. On a small scale I have raised a column of mercury 9 inches. From these data you can calculate the immense velocity of current which may be produced in extreme cases, if such, which is improbable, can ever be required for discharging fire-damp.

"Two inches of water pressure, I believe is about that of a current of air travelling 86 miles per hour. I presume the pressure of rarefaction does not produce more than $\frac{1}{4}$ to $\frac{1}{2}$ inch water pressure. Do you know what it is in practice?[e] I have given you extreme cases as data by which possibly you may approximate to what you want, and to show you the excess of velocity capable of being produced by high pressure steam greater than can ever be required for the most foul or dangerous work." * * * *

Peculiarly fitted for ventilation of mines.

Viewing this question in all its bearings, its power, its safety and economy, facility of execution and command, the Committee cannot hesitate to recommend ventilation by high-pressure steam, as peculiarly fitted for the present condition of mines, and adapted for them in every stage of their operations.

Mr. Buddle objects to "too much ventilation as *being troublesome* ;" and even the hewers did the same at Wallsend, he says, because '*it melted their candles too much,*' and they frequently set the board-end doors open to slacken the current of air."[f]

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[d] This is the door alluded to by the Committee in the remarks preceding this letter, in which it is stated that a door is usually so placed, and that no communication takes place between the bottom of the upcast and furnace, and consequently for that and other reasons there assigned, the furnace drift is the best place for the blower and boiler.

[e] On trying an extensive colliery on the 16th February, 1842, we found the difference of the Mercurial Barometer, at 246 yards down, scarce $\frac{2}{10}$ths of an inch. The thermometer in the downcast being 56°, and in the upcast 102°. At the same time, with a curved hollow glass tube, 1 inch internal diameter, 2 feet long, the stalks being 1 foot apart, when filled to about 20 inches with water, the difference of water pressure was $\frac{27}{32}$ inch. Mr. George Stephenson found Killingworth, by the Mercurial Barometer, indicate a difference between the two shafts of nearly $\frac{1}{4}$℔. the square inch ; more than double that of the above experiment.

[f] Parliamentary Evidence, 2,039.

Too much ventilation troublesome—and the only reason assigned that it melted their candles too much! So that for this trifling and easily remedied inconvenience the country is to continue to have hecatombs of men perpetually sacrificed, and its mines every now and then shattered to pieces! The very proof of the objection at the same moment annihilates it. Setting the board-end doors open at once remedies the inconvenience, though at a risk. Shortening the brattice ends, which may be done in a few minutes, and allowing the air to take its sweep within a few feet of the men, will equally and safely accomplish this object. The air will, of course, take a shorter course in preference to a longer, and it will not force itself with violence into a *cul-de-sac* in which the men are generally working, except it be so directed by the barriers of the brattice. Were the men's opinions taken at all in the matter, they would doubtless express their willingness to be subject to the inconvenience of "melting candles" rather than the risk of destructive explosion: and while the whole mine was being swept clear of gas and impurities and kept cool, they would bear the inconvenience, or remedy it easily by a shorter brattice, a board-end door ajar, a small wooden screen, or a good lantern; which trifling trouble would be amply compensated, in addition to their safety, by a more healthy atmosphere, a reduction of temperature to an average of 50° to 55°, instead of from 65° to 80°, by which to mitigate their severe labour, and produce other important advantages. Were the ventilation, such as an improved system ought to produce, fixed and enlarged lamps, might be adopted in most parts of the mine: the naked light at many points, without hesitation, might be introduced, and perhaps at length a free employment of gunpowder used, if necessary, in many excluded and foul workings: and light and safety would exist, where now stalk darkness and death. And by a judiciously increased exertion of the tremendous steam power each morning before the men commenced work, not only might all the foulness of the mine be exhausted, but by the unusual rarefaction of the entire atmosphere below would the *pressure* against the surcharged recesses of the mine be *lessened* to such a degree, that the gas would escape at every fissure, which, on the decreased action of the ventilator, would again be sealed up by the more condensed columns of air.

Daily exhaustion of the gas by the steam ventilator.

Ventilation by steam recommended in Belgium.

Ventilation by Steam has already engaged the attention of Scientific men in Belgium.—In the Report of the Secretary to the Royal Academy of Sciences at Brussels, which accompanies some able Memoirs on Accidents in Mines and the Government Commissioners' Report on Safety Lamps, he observes, that one of the authors, whose memoir is not published, suggests steam for this purpose:—"Le troisieme moyen qu' il propose pour activer l' aerage *est connu depuis long temps*: c' est celui qui consiste á injecter de la vapeur d' ean dans la chéminee d' aerage."

M. Cauchy.

M. Cauchy does not state how long the application of steam ventilation had been known to him, but in page 19 of his report gives it, on the authority of another gentleman, as the suggestion of a Mons. Taylor. He says:—"Il etablit la ventilation par le procéde qu' il dit etre dû á M. Taylor, et qui consiste á faire arriver, *au fond du puits d' aérage, de la vapeur á haute tension* produite par deux chaudières;" and in page 23, speaking of the able memoir of M. J. Gonot, chief engineer of mines at Mons, he further states:—"Examinant et discutant les divers moyens connus de chauffer artificiellement l' air pour provoquer son mouvement continuel et suffisamment rapide dans les mines, l' auteur se pronounce formellement en faveur de celui de M. Taylor, qui consiste a introduire de la vapeur d' eau à une assez grande profondeur (200 met. par example) dans les puits d' expiration."

M. Taylor.

M. Gonot's suggestion, rarifaction and not propulsion.

M. Gonot himself thus writes on this mode of ventilation, which he much approves of, and recommends the following mode of its application:—"*L' on etablirait á la surface, une ou deux chandieres* a vapeur, auxquelles viendrait s' adapter *un tuyau* en fonte de 0m. 20 de diamètre, par example, que l' on placerait dans un des angles du puits de sortie, et qui viendrait *deboucher à peu près au pied de ce puits, par son extremité inferieure recourbée verticale* *ment* de manière à donner à la vapeur, comme au courant d' air, une direction ascendante."[g]

M. Gonot, in recommending the steam to be brought from boilers at the surface in a pipe to the bottom of the upcast, and there, with its mouth turned upwards, the whole volume to be discharged into the entire column of air, does not appear to intend any thing more than its rarefaction, or, if he thought to aid it by the force of steam in such construction, he seems not aware of the almost certainty of injuring the intended effects, as pointed out in Mr. Gurney's lucid exposition, by producing a circular instead of a perpendicular ascending movement, effected by the partial application of the steam acting only on a portion of the column. M. Cauchy, the reporter, in detailing the recommendation of another memoir, uses the term, "*vapeur a haute tension*," as if an indistinct idea was entertained of employing the forcing action of steam at high pressure, as well as its rarefying power. The plan of operation proposed by M. Gonot, and favourably introduced by M. Cauchy, would tend only to disappointment, if any other motion was anticipated than that by rarefaction.

The following extract from a note of Mr. Gurney's, date June 3, 1842, will explain his opinion of the Belgian views :—

> "In regard to Mon. Gonot's paper, you will observe, on a closer examination, that he *entirely overlooks the just principle* in the action of steam for coal mine ventilation, and only treats of a weak and ineffective modification for heating air, which has been proved over and over again to possess little, if any, advantage over the ordinary mode of ventilation by the furnace. This seems to me very extraordinary, and I think your report may be considered more valuable if this fact be pointed out, while attention is drawn to the importance which has been attached to steam as an agent for ventilation by scientific foreigners, one of whom has been rewarded by 2,000 francs, principally on account of proposing a comparatively powerless application.
>
> "I think it well to remark that the mode, as I have proposed it, may in case of danger, or under local circumstances requiring it, be carried to any distant or obscure spot in the galleries, and made to effect any intensity of ventilation there ; and if at such distance as to receive too much loss by condensation, compressed air may be substituted for steam to produce the same amount of current : of course, with increase of expense, which the nature of the necessity must sanction,"

Mr. Gurney, the original proposer of high-pressure steam ventilation.

As Mr. Gurney, so early as 1835, made to the Commons of England the suggestion of high-pressure steam for ventilation, which was then recorded and published, it displays considerable ignorance of this subject in M. Cauchy and the authors of the memoirs explaining it, to adopt for recommendation a very imperfect mode of its application ; and it can scarcely be permitted, four or five years afterwards in Belgium, that the suggestion of steam ventilation should be ascribed to another.

This is one of those public errors which require only naming to be rectified. If the mere hint of steam ventilation be sufficient to secure the merit of a discovery, then does it really belong to Mr. Buddle, of Wallsend; for so early as 1813, in his letter to Sir Ralph Milbanke on the prevention of accidents in mines, he explains and gives a drawing of ventilation by steam, in which, from a boiler like M. Gonot's, on the surface, steam is conveyed down a pipe covered with wood a little distance into the upcast shaft, where, by its heat counteracting its direction, it forms a sort of rarefied ventilation. But he does not himself approve of it, and no wonder. The pipe at its extremity is not curved even to open upwards, like M. Gonot's, so that the force of the steam's motion operates against that of its expansion—one principle counteracting another ; the former of which, the force, by a proper apparatus on Mr. Gurney's plan, *if required*, is strong enough to propel, in its own direction, the entire column with inconceivable velocity through the galleries, reversing Mr. Buddle's motion by steam rarefaction into one in a contrary direction. The more such an apparatus as Mr. Buddle's was exerted the less ventilation would probably, except in a wrong course, be produced. It is even a worse arrangement than that of M. Gonot's ; yet is deserving the credit of an original attempt at a beneficial change.

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[g] Memoire sur l' aérage des mines par J. Gonot, Ingenieur en Chef des mines a Mons, page 196. Des Moyens de soustraire l' Exploitation des mines de Houille aux chance d explosion, &c. &c—Bruxelles, 1840.

Double passages for ventilation.

In all the important and dangerous parts of the mine, there ought not only to be a separate and distinct passage or drift for the surcharged *return*, but also for the *intake* or advancing column of fresh air; for when those passages are filled with rolleys, corves, and horses, the obstruction is of a most serious nature. In improved pits, the Committee are glad to know, this point is being more carefully attended to.

Gas Drifts.

Tapping and draining the gas.

While the Committee are anxious to express their strong conviction of the necessity of an improved and freer system of ventilation, they cannot overlook the additional security to be obtained by a better attention to the nature of *gas drifts;* and they believe that by the adoption of a scientific mode of tapping and draining the gas by these means, in conjunction with complete ventilation, the coal mine may eventually be rendered almost as healthy and safe as the field of any other laborious profession.

Dr. Hancock's suggestion.

The Committee have had a very ingenious paper transmitted to them, with a strong recommendation by the late lamented and scientific Dr. Birkbeck, from Dr. Hancock, of London, which contains in it the principles of operation of a system proposed and effected in Staffordshire by Mr. Ryan, but which, to the extent and in the manner laid down in Dr. Hancock's ingenious essay, would be impracticable, inasmuch as the ponderous expense would render it impossible to be undertaken. However, it is deserving of attention, as containing the seed of a valuable principle clearly demonstrated. From which essay, and from Dr. Birkbeck's communications, an extract or two are now given.

Dr. Birkbeck to the Committee.

In a letter to the Secretary, dated, 38, Finsbury Square, Sept. 2, 1839, Dr. Birkbeck writes :—" Never since the investigation of the Parliamentary Committee, to which you refer, have I ceased to reflect upon the painful subject of explosions in coal mines. The continued, often-repeated destruction of human life is too formidable ever to be forgotten by me; and I frequently feel deep disappointment and regret, that the immense mass of valuable, practical, and scientific evidence obtained some years since, has been permitted to remain completely unproductive, as regards the prevention of those dreadful accidents which occasioned its accumulation. Why all this information has happened to be thus disregarded, I shall not at present attempt to determine. I will merely hint at one probable cause: the insolence of some persons calling themselves practical men. And this I shall do, not for the purpose merely of complaining—although I certainly do complain of this conduct—but likewise to introduce you to the knowledge of a valuable speculation placed in my hands about the beginning of the year, when I was an invalid, by a very ingenious and benevolent physician. This speculation came to me in the form of an essay on the ventilation of mines; and it was the object of its author, Dr. John Hancock, to recommend a plan, which I designated as most appropriate—*self-ventilation. It was founded on the acknowledged difference of specific gravity of carburetted hydrogen gas and atmospheric air,* and the possibility of making the roof of the mine shelve upwards, so as to form a channel for the gas, which instantly endeavouring to ascend might glide along the inclined passage until it reached the shaft of the mine, or smaller openings or shafts sunk in such places as might be most convenient for this species of ærial drainage. The plan was pretty well made out by Dr. Hancock, and I gave him a favourable opinion respecting it."[h]

[h] This distinguished and enlightened philanthropist, Dr. Birkbeck, was himself devoting his scientific and practical mind to the whole subject, as this Committee learnt from several interesting letters, when ill-health interrupted, and death eventually for ever terminated his humane endeavours. The Committee felt much satisfaction in his anticipated suggestions and the approval he was pleased to express of the course of their proceedings. He says, in one of his communications, "It is probable that I may have a few suggestions to offer respecting preventative measures, and the mode of directing the attention of miners to the occurrences from whence mischief afterwards arises. Whether useful or not, I shall venture to offer them when a little matured, believing that the spirit by which your Committee is influenced, will lead to a fair and dispassionate appreciation of their quality."—This Committee can only regret their loss, and in common with their country mourn for one who has done so much to develope the intellect of Britain, and who has erected a living monument in every heart.

Dr. Hancock states in his *essay*, that "little improvement indeed can be expected whilst the present methods are pursued; whilst freedom from the *fire-damp* depends on the continual *coursing of the air*, and expelling the gas by force; or whilst it is allowed to accumulate under vaults or recesses, and to be ever purposely boxed in or confined by walls, stoppings, trap-doors, &c. And passing strange to say, all this cost, all this trouble, anxiety, and peril, are encountered to remedy an evil arising *from the confinement of a subtle fluid, which is of itself ever seeking to escape, and to effect which no forcing is required: no other assistance than a free pathway to be given it.*" * * * * * * "One chief point seems not to have been adverted to by the miners, nor even by those who have professed to make it their study, namely, *that it is the confinement of the gas only which causes it to explode with destructive violence when fired: that it will not explode with violence when free or unconfined, any more than loose gunpowder*, which, ignited, flashes without violent concussion or loud detonation. Yet has it been long known that condensation is requisite for augmenting the explosive power of gases: in fact, *that they can scarcely be exploded without some degree of condensation*, to procure which all elastic fluids require confinement.[i] It should be considered that carburetted hydrogen is only half the weight or specific gravity of the atmosphere at the surface of the earth; and the greater will be the difference the lower we proceed." * * * * * "Deep mines are thought to be more infested with the fire-damp than more superficial ones. There are two causes to be assigned for this: first, in those mines which lie near the surface, more of the gas exhales or finds its way into the atmosphere than from deep mines; secondly, the pressure of the superincumbent atmosphere, and the consequent condensation of the gas, will evidently be greater in proportion to the depth of the mine. When, therefore, in a deep mine the gas becomes confined and pressed up under an arch or vault, *remaining long therein*, it forms an explosive mixture, and on being ignited detonates with great violence."[j] * * * * * "Taking these facts into consideration, why not, I would ask, *take advantage of the inherent property of carburetted hydrogen to ascend, by allowing, from the moment of its emission, a free and unobstructed escape out of the works?* This requires no ventilation or forcing currents of air through the mine, but simply a removal of all obstacles to its natural course, which is to be done by *cutting away all depressions in the roof*, so as there to form a *gas drift or channel*, overhead, *ascending out towards the shaft*, or to a perforation made by boring down from the surface, or by an additional small shaft."

Elastic fluids require confinement or condensation for explosion.

Ascending passages for the escape of gas.

He goes on to say, that self-acting and free from the errors of human agency and all the machinery of trap-doors, stoppings, &c., it will always be producing the desired result "*on the principle of the drainage of land reversed; the water tending downwards by its gravity, and the gas ascending from its levity or buoyancy*. But the gas will move with much greater velocity than water; the velocity of all fluids being proportionate to their levity." Thus acting, it will be free from the fearful contingencies of the unremitting care and negligence of the ordinary attendants of the mine. And then, he adds in a note, to shew the necessity of this:—"When the Wallsend Colliery exploded, with the loss of 102 lives, it was said to be under the best ventilation, and a constant use of the safety lamp; and the same was the case at the recent explosion of St. Hilda: the same too was asserted of the explosion a short time ago at Harrington, in which all in the mine (40 persons) were destroyed. In all cases, although no survivor is left to tell the tale, some means are found out to account for the accident, as the carelessness of some overman or other servant. The farce of a coroner's inquest ensues; the usual verdict of accidental death is returned; the affair is then considered as settled most satisfactorily, and consigned to oblivion."[k]

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[i] It may be observed, that in all the explosions of mines, it is not in a confined space, but in the open boards or galleries, into and from which the air has free passage that they occur. And that there is no condensation greater in those horizontal galleries than what the atmosphere somewhat rarefied at the exit of the mine, may give to this elastic fluid; but yet that it is considerable may be inferred from the rapidity with which a balloon, when filled with it, ascends into the air.

[j] Carburetted hydrogen gas being retained in a confined situation, as in old closed workings, becomes anti-explosive from the production and mixture of carbonic acid gas; but it is presumed Dr. Hancock means a collection of gas only sufficiently long in such a situation to admit of its admixture with air to bring it to the explosive point.

[k] Dr. Birkbeck thus writes to Dr. Handcock on his plan:—"You have spoken of your plan in the paper before

Objections to Dr. Hancock's plan.

The extensive excavations in an inclined or sloping direction would be impracticable from the enormous expense which would be required for their execution; for they would be stone drifts, yielding not the slightest produce, and a costly outlay. Moreover, it would only be the point of contact at a low angle, which would be exposed in a flat mine, generally the most dangerous, to the efflux of gas from the coal. They must follow the line of the seam to be of use to drain the entire working, and the dip of some mines, interrupted by faults, sometimes ascending, sometimes descending, would render draining the gas by such inclined drifts, as described by Dr. Hancock, impossible to be accomplished. This scheme, therefore, of Dr. Hancock's, is not practicable.

Single gas drifts.

But for draining the mine of its redundant gas, there is no necessity for such an extensive series of subterraneous tubes: the simple proposition of a *single gas drift,* as suggested and effected by Mr. Ryan, and adopted in Staffordshire and Worcestershire with great success, seems to be sufficient in most cases, if judiciously executed.

Dykes dam back the gas, and probably produce more gas by increased electrical action.

The semi-elliptical basins of coal, with a dip from the horizon of from 6 to 15 degrees which generally obtains in the British coal measures, from their inclined position, enable the gas by its natural levity to rise towards the surface, along the interstices, cleavage, or *backs* of the coal; so that when, as in some parts of the country, the coal strata lie at no great depth, or *crop to the day,* as it is called, the gas escapes into the atmosphere, and consequently almost all shallow mines are comparatively free from gas. But should they lie at any great depth, the pent up gas, unable to escape, compressed and confined by the superincumbent impervious strata, surcharges every crevice and pore, especially in the rich coal of the north. Still, however, following the law of its nature, it seeks to ascend, and is found dammed back by the *faults, dykes, slips, troubles, and dislocations,* beneath which it is commonly found accumulated, and which not only intercept it, but it is probable produce a different electric condition of the strata, and generate in their neighbourhood a greater quantity of gas by the increased action of a more concentrated electricity, although tolerably free in other parts of the strata.

Mr. Smith says, in his Parliamentary Evidence, 3,816:—"Gas has appeared approaching a dyke where none was ever observed before." Mr. Buddle states, 2,161:—At Jarrow, "it is a fault, a slip-dyke, which makes a line of demarcation between the foul part of the mine and the comparatively clean part." And Mr. Forrester relates, 2,763:—That in a certain pit they were working, they "came to a dyke or fault where a sudden stream of hydrogen came out, flowing from the slip or dyke."

There are often fissures in the slip-dykes which are formed by the latter, chiefly when sandstone abuts against sandstone, according to Mr. Wood,[1] extending to great distances in the coal field, receiving and collecting the gas, and carrying it as along natural gas drifts of small size, which, when entered, discharge their contents with great force as blowers that sometimes continue for years. Here then are natural operations: the passage of gas through the longitudinal divisions of the coal till stopped by the dyke; its discharge by a pipe intersecting its course, and the drainage of the other parts of the coal stratum, which all afford strong prima facie evidence of the eligibility of Mr. Ryan's plan of gas drifts along the face of the dykes.. From the adoption of which in Staffordshire and Worcestershire, so much benefit has

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alluded to, as being proofs of *draining*: with the drains, on account of the nature of the fluid, ascending towards their termination instead of descending, as when water is to be conveyed by them. We may now consequently speak of draining coal fields, as we have been accustomed to speak of draining fields for growing grass or corn. The gas drainage will, however, be more easy than the latter, because we need only make a constantly and regularly ascending path along the roof of all the passages within the mine, until we arrive at the common shaft, where all the streams will at once rush upward; or when the chambers are too extensive, a sufficient number of smaller shafts or perforations must be made to admit of the escape upwards of the currents of gas poured into each of them from their respective branches. Even under the most unfavourable circumstances, when, for instance, by perforating the walls of a cavity containing the carburetted hydrogen in a state of compression a blower may be formed, mischief cannot arise. * * * Under this most judicious arrangement for the escape of the explosive gas, it is probable that the use of the safety lamp would be rendered unnecessary."

[1] Parliamentary Evidence, 847.

already been derived, that its principle seems only to require to be correctly understood to be more generally practised.

Mr. Ryan's plan.

So early as 1808 Mr. Ryan tried his plan in Staffordshire with success, previous to which, in the same mines, the "firing line," that is, exploding the gas from a secure recess, with a wire and candle several times in the day, was practised to the injury of the works and the health of the miners. There is the most unexceptionable evidence of its important advantage and almost general adoption in the mining districts of Staffordshire and Worcestershire up to the period of 1818. And the London Society of Arts, satisfied of the correctness of the principle, in 1816 by the hands of its President, the Duke of Sussex, presented Mr. Ryan with 100 guineas and its gold medal. Time and experience, the destroyers of error and the supporters of truth, have strengthened this conviction; and in 1835, we find the enlightened mine engineer, Mr. Smith, thus supporting it before the Parliamentary Committee.[m] "He (Mr. Ryan) certainly threw some light on the principle of ventilation. He made use of some air-pipes, which he carried from the mouth of the small head up to the upper workings of the thick coal; and by converting the head into an upcast, instead of a downcast head, he by that means took out the inflammable gas that was hanging overhead, and *thus drained the side of work completely. This led to the introduction of making top-heads generally.* By this means all *top-heads* in future were put into the *upcast* shaft *instead of the downcast*; and I believe *ever since that time this system of ventilation has been found quite sufficient for the Staffordshire mines.*" * * "I always considered there was a great deal of merit due to Mr. Ryan for that suggestion."

The cleavages in the coal permit flow of gas to the dykes.

Draining a side of work of a 30 feet seam, with the gas-drift running along its upper edge, may be said to be different from draining a 6 feet seam where the gas, except by the gradual ascent of the stratum, is not impelled to its more distant gas-drift. The great law of specific gravity still, however, operates as strongly in the latter case as in the former, and it will find a passage through the longitudinal cleavage, or ooze through the pervious fractures of the coal, as water would descend, but with more certainty and force. Besides, the pressure of the gas perpetually increasing, will overcome more than slight obstructions, till a passage is obtained, and will facilitate its ascent to the common drain. In some instances this pressure is very great, forcing off sections of the coal with the strength of gunpowder; and in an instance detailed to the Committee by Mr. T. J. Taylor, of Earsdon, whose scientific research into the phenomena that present themselves in mining is of great value, it is stated to have assumed that of $4\frac{1}{6}$th atmospheres, or the full power of steam employed in a high pressure engine. This occurred at a *water-blast* in Percy Main Colliery in 1840, and Mr. Taylor calculated it discharged 12,686,000 cubic feet of gas in 68 hours.[n] A pressure such as it is capable of assuming will aid in forcing passages up towards a dyke, where it will gorge, but on the intersection of the termini of the cleavage will freely discharge itself and flow off by the gas drift, to which could steam be applied to form a *partial vacuum* or *great rarefaction*, as before suggested, it would extract the gas as a cupping glass does the fluid from the veins.

Gas capable of assuming high pressures, will force itself passages to a dyke.

Mr. Ryan thus describes his plan:—"When these faults occur they merely act as dams for their whole length, and the ends of the coal that lie against them should be separated by making a road along: simply make a passage for the gas, and when you can once get in a portion of the gas, another portion will come in in proportion as you rarefy, and the gas will flow then in greater quantities." * * * * "I would say if the gas course above, or at a mile or two miles distant, did not cut the blower off—taking the ends of it—if it did not cut off the blower, I would then consider there was some additional fault that had come in between that. For instance, some blowers will yield 700 or 800 barrels of gas per minute. In proportion to the extent or quantity that the blower discharges, I conceive that the extent of the fault may be measured; the effect of the fault should be further removed; for when the faults come in very close together, the blowers will then yield but very little gas; they have not space to work upon, the tube is so much shorter." * * * "It appeared to me from a patent I had for draining faults and draining mines, and bringing up part of the strata or coal of the earth, that I found *when I was far from a fault, or when there was no fault behind me, the quantity of water was immense that was raised. In some places where I bored I found there was no water;* go down what depth I would no water would come. It was that at first led me to the idea that mines might be drained on the same principle."[o] These observations are sustained by the well-known effects of those *dykes* or *faults* already remarked on.

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[m] Parliamentary Evidence, 3,021.

[n] See Mr. Taylor's Minutes in Appendix.

Other effects of dykes besides damming back the gas.

Professor Buckland states in his inaugural lecture, after pointing out the great advantage of *faults,* in elevating conveniently nearer the surface strata that had a continual tendency to bury themselves out of reach, that "a still more important benefit results from the occurrence of *faults* or *fractures,* without which the contents of no deep coal mine would be accessible. Had the strata of shale and gritstone that alternate with the beds of coal been continuously united without fracture, the quantity of water that would have penetrated from the surrounding country into any considerable excavations that might have been made in the porous grit-beds, would have been insuperable by the most improved machinery; whereas, by the simple arrangement of a system of faults, the water is admitted only in such quantities as are within controul." The same principle, (the relative specific gravity of fluids,) that admits water, only within the space of an elevated *fault,* to flow down into a mine that has its excavations below the level of such fault, will also admit carburetted hydrogen gas to ascend through the strata, or rather the *backs, slines,* or *cleavages* of the coal, till stopped by the impenetrable dyke. The lowest pervious depth being the natural barrier of the water—the highest pervious ascent that of the gas; and where water can penetrate downwards, the more subtle gas can easily ascend upwards.

Gosforth Pit was sunk on the above principle on the south side of the great dyke, and penetrated through it to the coal on the north of it, which enabled them to reach the coal without much interruption from water.

By the *down-throw* dykes, as observed by Mr. Conybeare, "valuable beds of coal are preserved within the field which would otherwise have cropped out and been lost altogether."

The great 90 fathom dyke of this district, varying from 15 to 20 yards broad, throws down the strata to the north more than 500 feet, and the great south dyke in Clackmannanshire throws them down upwards of 1,200 feet, but it is from the less extensive dislocations that the advantages above described are chiefly derivable.

Detached gas drifts in the northern mines.

Detached drifts are already in operation in the northern mines; but without consideration to the faults or the natural cleavage of the coal, they are merely pushed on before the working part of the mine to explore its condition, and serve to a certain extent to tap and drain the gas in their immediate locality. The same expense judiciously applied to form a drift along the face of a fault intersecting "backs," and opening into it lines of "blowers," would drain to an incalculable extent the whole underlying coal. Mr. Nicholas Wood states:—"Leading drifts, in some cases, are driven to tap as it were the mine before the general workings approach that part, and, as it were, to explore the danger; and in some degree these leading drifts draw off the gas, keeping the main body of the workings more free from such casualties."[p]

The great advantage of gas drifts scientifically applied.

From the support which the natural position of coal seams, their structure and their interception by faults or dykes, gives to the suggestion of draining by gas drifts, scientifically applied, borne out by extensive practical demonstration of its advantage, the Committee cannot conclude their report on this part of the subject without expressing a strong and decided opinion in its favour, urgently recommending its early adoption in every mine where gas is expected or known to exist. And as no interruption of the slightest kind to the present mode of operating in mines will occur by its introduction, and the expense will be comparatively trifling, they trust and believe that ere long it will be generally adopted.[q]

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[o] Parliamentary Evidence 2,897--2,916; and Mr. Ryan's Pamphlet, "Appeal to the Proprietors of Collieries, &c." It is satisfactory to know that an able and ingenious director of mines in Belgium, M. A. A. M. Boisse, in a "Memoire, sur les explosions dans les mines de Houille," 1840, speaks of the "avantages incontestables" of such a plan as Mr. Ryan's.

[p] Parliamentary Evidence, 1,097.

SCIENTIFIC INSTRUMENTS.

In addition to the safety-lamp, there are two or three other scientific instruments also valuable indicators of the state of the mine, which, if commonly employed and correctly observed, would give such clear and unerring intimation of coming danger from discharges of gas that nothing but the most criminal neglect could bring on these fearful catastrophies.

The *barometer, sympiesometer, thermometer, anemometer,* and *eudiometer,* if properly employed, add a new sense to the miner, and enable him in his darkness to penetrate with certainty into physical changes on which will depend, in a few hours, the existence of himself and friends. At present, without them, he is ignorant of these operations till developed and advanced he finds himself involved in them almost beyond remedy, or too late knows of their completion by the dreadful result.

The barometer and sympiesometer.

The slightest change in the pressure of the atmosphere is immediately indicated by the gas tubes of the coal: every pore, crevice, and blower, is a natural sympiesometer that is immediately affected by it. When the pressure is decreased, say 1 inch by the barometer, or nearly ½lb. pressure taken from every square inch, it enables the gas which is surcharged in every space of the coal to pour out in great quantities. But should the atmosphere fall to a very low range, and remove the weight of upwards of 1lb. from each square inch, then the elastic gas which has been generating under that pressure rushes into the mine, sometimes in such force and quantities as to foul every passage up to the very shafts in a few hours. When the atmosphere returns to its former condition, the gas is once more pressed back and is condensed in its recesses; and if the change occur rapidly, a perceptible rush and sound of the air into them on its return may be observed. *The barometer is an infallible indication of the gaseous state of the mine:* yet with one honourable exception, that of Wallsend, no mine that the Committee have visited had for the use of its officers such an instrument.

Certain indicators of the state of the mine as it relates to gas.

The effects of the fall of the atmosphere, as described, are much increased by an increase of the temperature, and certain directions of the winds: and what is extraordinary, in the northern hemisphere these favourable meteorological circumstances for the escape of gas are frequent coincidences.

The combined indication of the barometer, thermometer, & wind.

When the barometer indicates a fall, the thermometer a rise, and the wind blows from the E., S.E., or S., an ordinary fiery mine will be certain to pass rapidly into a state of great danger. It has, indeed, been commonly observed by the miners that their pits are always most dangerous in *S.E. and S. winds;* but the winds are only natural indicators of the state of the barometer and thermometer, although not always; the instruments most frequently preindicate the winds, for it is *then* the thermometer anticipates them and rises by the increasing temperature and the barometer falls by the decreasing pressure.

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[q] The Committee beg to refer to an ingenious Paper by Martin, the celebrated artist; and Letters on Fan Ventilation by Mr. Fourness, of Leeds, in the Appendix, for further Illustrations of Ventilation, &c.

M. Dove's observations.

M. Dove, of Berlin, from a long series of observations, has been led to conclude that the *barometer falls during E., S.E., and S. winds;* passes from falling to rising during S.W.; rises with W., N.W., and N., and has its maximum rise with N.E. winds.[r] He observes also, that the *thermometer rises with E., S.E., and S. winds*, has its maximum with S.W.: falls with W., N.W., and N., and is at minimum at N.E. M. Dove has also observed that the *elasticity of vapour increases with E., S.E., and S. winds*, has its maximum at S.W., and diminishes during the wind's progress by W., and N.W. to N., at N.E. it is at its minimum. *The law of the elasticity of vapour applied to the elasticity of gas, in conjunction with expansion by heat and lessened pressure of the atmosphere, clearly accounts for the certain, invariable and rapid flow of gas into the mine: while from the increased temperature and decreased weight of the air, the downcast and upcast columns approach nearer to an equipoise, and consequently a more sluggish ventilation is produced; which all coincide to bring the mine into its most dangerous condition.* A little foresight—an observation of the barometer, thermometer, and wind, an hour or two before, will give ample time to remove the men and prepare for the threatened mining storm.

Miners, as before remarked, have observed the connection between the pressure of the atmosphere and direction of the wind, and the effects upon the condition of the pit. Anthony Winship says (Parliamentary Evidence, 421):—"We generally think when the wind is from the south that the hydrogen gas is more quick and severe than at any other times:" that is, when the barometer is low and the thermometer high. In a south wind, increased brilliancy of the flame from the gas-pipe at Wallsend by an increased flow of gas is often observed. Mr. Wood says:—"A fall in the barometer occasions a considerable change in the quantity of this gas (the carbonic acid) discharged; if the barometer rises, the gas then withdraws to the old workings." Mr. Stephenson states, that "it was a common observation of the wastemen that the explosion was caused by the south wind."—(Parliamentary Evidence, 863, 1,685.) And "I believe it very rarely happens that accidents have taken place to any great extent but only at the time when the barometer stood low. Now if a good large barometer was kept at the bottom of each mine which the overlooker, the wasteman, or those that have any charge, should have an opportunity of seeing, would put him on his guard in some measure to look out for danger." It is not quite clear what is meant here by a large barometer: probably a good one, in a conspicuous situation. When Dr. Paris was completing the Life of Davy, Mr. Fenwick wrote to him that the mine became suddenly charged with gas when any atmospheric change caused the mercury in the barometer to sink to 28½ inches or thereabouts. In a letter to a Member of the Committee, T. Drewett Brown, Esq., the proprietor of Jarrow Colliery, writes:—

"Jarrow Colliery Office, September 24, 1839.

"DEAR SIR,

T. D. Brown, Esq.: observations on the barometer, as an indicator of gas.

"On the 1st of September, I find the *barometer stood at* 28·81 *inches.* The master wasteman's account of the state of the air in Jarrow Pit on that day is, *that it was so bad the gas came to the shaft.*

"On the day of the great storm (the 7th January), *my barometer was down to* 27·48 *inches;* and the wasteman's account is, that he seldom, if ever, knew a pit to be in such a state. *The gas came to the shaft in the Bensham, and having made its appearance in the Bensham engine chimney, it was found necessary to extinguish the fire.*

"The wasteman says, that '*the glass does not fall two degrees without a change being perceptible below.*'

"I have ever impressed on the officers to pay attention to the fall and rise of the mercury; and I am often told it is a good guide."—I remain, &c., &c.,

T. DREWETT BROWN.

In this enlightened coal-owner's communication, the evidence of the great utility of a barometer is strong and decisive; yet in or about Jarrow Colliery, there is no instrument of the kind officially attached to the mine, but accidental possession of one by the officer enabled him to make these observations. The attention to the subject is highly creditable to this gentleman, and its non-adoption openly in the mine, or at its surface, merely indicates the disinclination of practical men to adopt even a recognized improvement, and the necessity of a formal and powerful recommendation to produce its general introduction.

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[r] Mr. Snow Harris stated, at the British Association in 1839, on the Progress of the Meteorological Observations at Plymouth, with the barometer and thermometer, "that the hours of the greatest pressure were 10 A.M. and 9 P.M. The hours of least pressure were 5 A.M. and 3 P.M. Of the monthly pressures, October and December were the greatest; November and February the least; January and September the two nearest the mean. The pressure was least at the new moon, and increased up to the last quarter when it was greatest." At Inverness the maximum pressure is 4 o'clock A.M. and 3 30 P.M. The maximum and minimum are regular in time as relate to each other, varying only with the latitude.

The sympiesometer.

The sympiesometer, from its delicacy and susceptibility to changes in the atmospheric pressure—preceding the barometer commonly from four to five hours in its indications—and having an elastic fluid similar to that of the mine for its source of action, seems peculiarly fitted for the purpose of an indicator of danger in the mine. It is, besides, less easily injured, and may, if required, be removed from place to place without chance of derangement; and the mercurial barometer, less sensitive than the gas, only demonstrates the escape of the carburetted hydrogen a short time previous to, or at the moment when the mine has fouled and the danger arrived, perhaps, in some instances, too late to adopt the necessary precautions.

A sympiesometer and thermometer in every mine.

The Committee therefore recommend that a *sympiesometer* and *thermometer* be placed *in every pit*, in a convenient room, as an improved lamp-room, under the care of an intelligent and responsible person, with a few simple instructions, and that every officer of the mine have an opportunity of observing them at all times, and should their keeper perceive any material change in their indications, then immediately to give notice to the proper authority.

ANEMOMETER.

Present modes of measuring velocities of air.

The mode of measuring the rates of currents of air in mines is very imperfect, and in little accordance with the improved condition of science; for there is at present no instrument of any description, scientific or otherwise, for this purpose in actual operation.

In practice the velocity of air is ascertained by the smoke from gunpowder, or from tobacco, by the candle or soap bubbles. A certain distance (say 20 yards) is measured in the air passage, and then, by exploding a small quantity of gunpowder at the commencing point of this distance, the exact time the current conveys the smoke the 20 yards is observed by a stop-watch, the party keeping time noting its arrival at the extreme point. In a similar way the rate is found by floating soap bubbles, which may be used in an explosive current: while gunpowder, as well as tobacco smoke, can only be safely employed in a clean passage.

Their errors.

By these modes it is probable, from the greater density of smoke and soap bubbles than that of the air, that the exact rate will not be procured. When the candle is used, a man with it lighted in his hand, held aside so as to receive the full current of air upon it, walks along the gallery for 30 seconds or a minute, at such a rate as will allow the flame to rise exactly perpendicular; for if he walks faster than the current the flame will incline backwards, if slower, forwards. In this case, in addition to the difficulty of the steadiness of pace to be regulated by an extraordinary quickness of eye, there is probably another source of error, and a greater velocity is indicated than that of the real current, by the man's body narrowing the area of the passage, which will increase the rate immediately around the flame. From these practices of measuring the ventilation of mines great errors naturally arise; and a correct instrument for that purpose would be a valuable acquisition.

The anemometers of Professor Whewell and Mr. Osler

The anemometer of Professor Whewell, as described at the British Association of Dublin, 1835, seems to be too complex; and that of Mr. Osler, invented in 1837, appears too delicate, and both perform unnecessary operations, as the indications of the direction of the wind and its successive changes, to be quite fitted for the purposes of indicating the rate of air-currents of mines. It is probable that a more simple application of the principles of these ingenious instruments would efficiently supply the want of a mine anemometer.

Mr. Elliott's anemometer.

An anemometer constructed by Mr. Thomas Elliott in 1835, when an overman at Pensher Colliery, met so strongly with the approval of the coal-owners, that in that year, at their meeting in Newcastle, they presented him with 10 guineas for his invention, *but did not adopt it in one of their mines.* The Committee are now in possession of the original, which has never been copied, although its utility is undoubted. They have tried it in the mines with satisfactory results, and can recommend it as a sure instrument, well adapted for its useful object.

The inventor thus describes it:—" The works are enclosed within a case 12 inches high, 12 inches broad, and 4½ inches thick, with an oval top, and a ring to carry it by from one part of the pit to another; on the dial of this instrument, which is moved by the air acting on four wands, similar to a windmill, two concentric circles are described. The inner circle is divided into 48, and the outer into 60 equal parts. It has two indices or pointers, whose axes of motion are the centre of their circles, exactly like the hands of a clock: the one A points to the outer circle, and the other B points to the inner circle. The angular velocity of A to that of B is as 2,880 to 1. Hence, for every complete revolution of B, A makes 2,880 revolutions, and for every 60 revolutions of A, B passes over one of the equal parts into which the inner circle is divided. I have constructed a table (from some hundreds of experiments), by means of which, and the instrument, the velocity of air in a mine may be found with the greatest ease and dispatch, and also the progress the slow or registering pointer will make in any given time, and at any rate at which the air may travel."—A table is then given.

An advantage this instrument possesses is, registering the rate in the absence of the viewer, for one or two days, as well as indicating the velocity of the then present current.

It would be desirable to have an anemometer of this description under the continual inspection of the furnace-keeper, instead of the barbarous substitute of a piece of wood or thin hoop suspended by a string, whose increased or diminished inclination from the perpendicular denotes the rate of current to guide the furnace; which, or some other equally, rude attempt at an anemometer, the Committee have frequently observed. In addition to an instrument of that kind in the furnace-drift, another in one of the main air passages under the eye of the keeper of the other instruments and lamps, and open to the general inspection, would be a useful and valuable check to errors of ventilation, or neglect of overmen in the waste producing interrupted circulation.

The eudiometer.

Another instrument capable of valuable application in the mines is the *eudiometer*, for ascertaining the purity of the air. It would not only enable the officer to discover in any part of the workings, at any time, the quantity of oxygen, but also the percentage of carburetted hydrogen or other gases, without which their proportion and state of dilution by atmospheric air from ventilation, and the consequent safety of the mine, is mere guess work, except from the uncertain hint at the flame of a light.

The above instruments seem indispensable to every well-regulated colliery; to which a scientific officer would, of his own accord, probably add an electroscope to satisfy himself what effect, if any, fluctuations of electricity, atmospherical or terrene, might have upon the production of gases and the general condition of the mine.

The scientific instruments necessary for mines.

The necessity then of adding the *anemometer* and *eudiometer* to the *sympiesometer* and *thermometer*, as scientific instruments for mines, the Committee consider too clearly evident to require further elucidation.

BOYS IN MINES.

A great source of danger in mines, in addition to the inhumanity of the practice, is the employment of boys of a very early age, frequently much under 10 years, whence have arisen explosions and accidents of a very serious nature.

Instances of accidents produced by boys.

An explosion of carburetted hydrogen on January 17, 1826, in Jarrow Pit, which killed 34 persons at a blow, was produced by a boy 8 *years of age*, called Norman, who had left a "*trap-door*" open that had been entrusted to his charge, by which the ventilation was interrupted and the gas accumulated and exploded.

Last year, (April 19, 1841,) when Willington Pit "*fired*" and destroyed 32 human beings, it was given in evidence, at the coroner's inquest, that it was caused by a boy 9 *years old*, a "*trapper*," named Richard Cooper, who had left his door open to go and play with another little boy who had charge of the adjoining door.

Also when Thornley Pit exploded, 5th August, 1841, and killed 9 persons, Robert Gardener, a boy 9 *years old*, who had left school only 10 days before, was stated in the evidence of the viewer to have been the cause, by neglecting his "*trap-door*," by which the current of air was turned and destroyed, the gas thereby was allowed to accumulate, and on the approach of flame fired.

In addition to these and other grave accidents, there can be no doubt that slight explosions, which burn and injure individuals, are continually occurring from placing children of such an age in charge of those "trap-doors:" they are the directing valves of the vital fluid that keeps the whole mine in life and action, and the slightest neglect of which brings on such terrible results.

The fault cannot reasonably be imputed to the poor children, ignorant of the consequences of their acts, cooped up alone in the dismal silent darkness of the pit, sitting for twelve hours unrelieved from the monotony of their solitary employment. In such a situation it is not wonderful that the natural thoughtlessness and activity of their years should prevail, and that they should seek relief a little distance off with another imprisoned child, and leave their district exposed to all the consequences that now and then occur. The wonder rather is, that these accidents do not more frequently take place.

A party of this Committee was once placed in a favourable position to view how easily such results are effected. On a visit to a very important mine of the northern district, abounding in the explosive gas, they passed through a *board-end* door to the *face* of the coal, which door had been propt open to admit "the putters" and their corves freely in-and-out; when, on reaching the *face*, as the gas was perceived bubbling and hissing from its pores, a member bearing a naked light applied it close to the coal, and immediately a sheet of flame flashed all around and covered the roof of the *board*—(the passage they were in)—an alarm not only to them but to the viewer and men took place; and the flame was with some trouble extinguished by the men hastily "dashing" it with their jackets and by the door being again set right. It was quite evident, had it continued open previously a little longer, that the increased quantity of gas would have been sufficient to have seriously injured, if not destroyed, most of the party.

Crossings.

For the chief air-veins of mines, "*crossings*" are becoming more frequently employed. An arch air-duct, thrown over another passage at any angle required to convey the current in another direction, prevents the so frequent employment of boys, and adds consequently to the safety of the mine. These air-ducts, instead of being built of mason-work, however strong, would be much safer, when not used as water levels or for coal drawing, if inclined drifts were cut in the solid stone, either above or below the level of the transverse passage, which would form so much stronger "crossings" that, should a fatal explosion occur, they would not be blown out, as too commonly happens, and which, in that of St. Hilda in 1839, was the cause of at least 30 deaths by "*after-damp*." This mode of crossing currents of air over air is deserving of a more extended application, as it would secure a greater exemption from human agency, especially of so uncertain a kind as children, in those dangerous points of mines. Careful, steady, and experienced old men, unfitted for active labour, and not boys, should invariably be employed in charge of *important* doors, wherever they exist; the difference of expense of 3s. or 4s. per week being too trifling to admit as a countervailing objection where so much is at stake. Numerous lives and much misery would have been saved to families, as well as the little victims themselves, had such an arrangement been always in existence.

Old men in charge of important doors.

As far as relates to the boys' employment in an unhealthy and unnatural situation and attitude, and the injurious effects upon their physical development, the report and evidence of the *Children's Employment Commission* have given too clear and ample, though somewhat exaggerated details, to require any thing from this Committee upon those points, and which, moreover, do not exactly fall within the sphere of their duties particularly to examine.

The North of England mining district, it is gratifying to the Committee to testify, has not, in addition to the misfortunes of its almost periodical calamities, to sustain the atrocious charge of accumulating permanent miseries upon innocent and unoffending children, so prevalent in the minor districts; nor is the disgrace of employing women or girls in any of its mines known in a single instance. And considering the nature and duration of boys' and young men's employment in the Northumberland and Durham district—too early commenced, and of too long continuance, yet of which their fathers are witness, and by whose desire they are so employed—it is surprising that *physical injury so small* should be the result. It is, nevertheless, most desirable for the better physical, moral, and intellectual development of this portion of the people, that their early youth in this, as well as in other mining districts, should be spent widely different from what it is at present.

Boys to work in mines at a certain age.

While this Committee therefore sincerely hope that the Legislature will, at an early day, be induced to pass an act to remedy this state of things, by restricting the employment of boys till a more advanced age, and for a more limited time each day, and preventing women and girls altogether from descending mines; yet they cannot refrain from observing, that if this period for commencing a pitman's life be too extended, there will be every probability of placing the mines in serious difficulties, by restricting the supply of pitmen. After every consideration which the Committee have been able to give to this very important subject, they are satisfied that extending the period of restriction beyond the age of 11 or 12 at the latest, would conduce to throw such obstructions in the way of free working of the mines, that some of them would be entirely extinguished, while all would be worked at a vastly increased expense, which would fall eventually on the public and the manufactures and arts of this country, to the advantage of foreign competition. Already the fine coal of Belgium at 1 franc 10 cents. per hectolitre, or about 11s. per ton at Ghent, is confronting with success the finest British in the markets of Rouen and Marseilles: and if to one port of the Mediterranean, then it is to be feared that eventually to more, or to all, and to other countries, it will find its way to the displacement of this important British export.

If the age too late, it will restrict the supply of labour.

At the age above specified a workman's son has had ample time, with his own future exertions, to acquire such education as his situation will permit or his parents can afford. To continue even to support his boys up to that period, with increasing expenses, is as much as may well be expected; and if prevented going to their father's employment, partially to relieve him from the charge, they will with his approval seek another where the restriction does not apply. And if pitmen's sons turn their backs upon the mines, it will be almost impossible to induce the grown up children of other sections of the community to attempt so irksome an employment, or even their parents to sanction it with their popular terror of its nature and its danger. The instances are very rare exceptions in which a boy not originally connected with the mines ventures upon such an undertaking. Besides, after the age of 12, habits are beginning to be formed and tastes acquired much more in accordance with the ordinary employments on the surface, and it is probable that then even a pitman's son may have grown into a repugnance to exchange the light of day, and the companionship of his fellows, which most other trades afford, for the solitary darkness of the mine, and its confined and severe labour.

This matter, about 30 years ago, was legislated on in France by Napoleon. In an imperial decree of the 3rd January, 1813, containing police regulations on the working of mines, several of them very excellent and humane,[s] it is ordained that no child under 10 years can be permitted to descend or work in the mines; which still continues the French, Belgian, and Italian law.

The age boys should be admitted to work in mines.

For the reasons, however, above assigned, and for humanity's sake and facilitating the better education of pit-children, the Committee feel it their incumbent duty to express their opinion that *the earliest period* for the admission of boys to work in the mines of this country should be 11, or, at the latest, 12 years of age, but that the restriction should not extend beyond the latter age, so as not to prevent the mines being adequately supplied at all times with skilful and experienced labour.

REGISTERED PLANS AND SECTIONS OF MINES.

The want of plans productive of serious injuries.

A serious omission in British mining, which has led to more than one fatal accident, is the want of a regular registration of the plans of mines. Twice in the Tyne district, within a few years, have the workings of an old mine been penetrated, and upwards of 80 lives sacrificed by inundation:[t] and at Workington, in 1833, the Lady and Isabella Pits were similarly inundated, and 4 lives out of 30 so destroyed. Besides, the escape of gas from them when too nearly approached, and the expense of boring and exploring drifts, when suspected to be in their vicinity, render the advantage, and, indeed necessity, of correct registered plans so imperative, that nothing but the absence of some superintending authority could so long have excused their omission.

In addition, as mines have been partially exhausted, or the best of the coal or the most valuable seams only worked by parties holding merely a lease of them, they are shut up, the remainder of the coal lost to the country and proprietors, till increased demand or facilities in mining present themselves, such as the Davy lamp, when they are again sought for and reopened; or more probably their precise locality is forgotten, and serious expense is incurred and mischief produced in the attempt, which might all have been prevented by an easy access to an official registered plan.

It seems also proper that the mineral wealth of the kingdom should be correctly known—what expended, what remaining rendered more accessible, and how best it may be preserved or economized for society and future generations. It is not like the soil on the surface, which exhausted may be renewed; or manufactures and commerce, which decayed may be restored by wise and energetic laws; but the mineral riches of England once exhausted, destroyed by superior competition, or rendered nationally unavailable by extravagance and waste, can never be renewed, and will bring with it a fatal termination to her prospects and pre-eminence.

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[s] Décret Coutenant des Dispositions de police relatives a l' Exploitation des mines, Titre IV., sc. ix., cl. xxix.

[t] In 1815, May 3, there were 75 lives destroyed at one inundation by the bursting in from old workings.

Registered plans and sections of Foreign coal countries.

During the time of the French empire they considered this subject of much importance, not only for the security of the rights of their government to whom the power of granting permission (concessions) to work their mines belonged, but also for the safety of the men and the works.

France.

It is well expressed by the Minister of the Interior, Count Montalivet, in his instruction, 3rd August, 1810, relative to a Decree of Napoleon, which, with some other mining laws, the Government of the present King of the French has most liberally supplied to the Committee, who can only regret their inability to reciprocate, from England, the civilized act, owing to our statute book containing no law on the regulation of mines. He says (Sect. IX.) :—" Une obligation essentielle qui doit aussi être enoncée aux actes de concession et permission, et dont les exploitans èclairès sentiront bien toute l' importance c' est celle d' avoir des plans et coupes des travaux á mesure de leurs progrés. Sans cette pratique indespensable, on est exposé a châque instant, dans l' interieur des mines, à toute sorte d' accidens desastreux. La confections des plans dans les travaux des mines est une mesure de sureté publique et de la plus grande utilité pour l' interèt de l' exploitant."

He then goes on to state, that the proprietor or adventurer (exploitant) shall address a plan of the workings of the previous year every January to the Prefect of his Department, upon a scale of a millemètre to a mètre,[u] which is to be joined to the previous plans, and sent to be certified and preserved in its archives by the chief engineer of the arrondissement. Napoleon again in his Decree of the 3rd January, 1813, reiterates their necessity with additional particulars, as a daily register of their progress, and any important circumstance of which it may be useful to preserve a record.

Italy.

Hainaut.

Belgium.

These laws containing such regulations extended over the Netherlands and Italy, as well as France, and have continued amidst all the vicissitudes of empires to retain their force. King William, of the Netherlands, in 1818, sustained them with certain modifications; and the province of Hainaut published a decree in 1823, based on that of 1810, especially ordering all plans, sections and vertical projections of mines, to be regularly prepared and preserved by the proper officers; and they still continue to be the guide of all the mining operations in Belgium. So that every great mining country of Europe possesses a means of ascertaining the condition, extent, and progress of its mines and mineral resources, except Great Britain, the most important of them all.

John Taylor, Esq., in his evidence before the Parliamentary Committee,[v] strongly recommends the advantage of maps. He says:—" Perhaps I may explain that I consider it more important to the public in collieries than in our mines: collieries being worked upon a horizontal plane, differ very much from our mines, which are worked upon a vertical plane : the beds of coal lie flat in a colliery, but mineral veins are either vertical or nearly so. Now it concerns future times very much indeed to know how far horizontal workings may be extended; and if the map is lost great danger may ensue to a colliery; but ours being vertical do not interfere with one another so much, there is not the same probability of breaking into old workings as in the other case; but in both cases correct sections and maps are, I think, most important things; and I believe the value of them is now very much appreciated, though it was not formerly."

Such is their appreciation in the north, that Mr. Wood states—" I believe in many cases the old workings are not correctly mapped;" but where they are suspected, " in all cases the practice is to carry leading drifts in the direction of those workings, and to bore as they are approached."[w] They were practising these exploring drifts and borings in 1815 when the water from an old working that had been relinquished in 1745, burst into Heaton Pit and drowned 75 people.

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[u] That is on a reduced scale of 1000: the mètre being 39·37079 English inches; the millemètre ·03937 English inches.

[v] Parliamentary Evidence, 178.

[w] Idem., 1,092.

Plans and sections at each mine, registered in each district.

The advantages of possessing correct plans and sections of mines are so very obvious, that the Committee will merely confine themselves to urgently recommend their adoption at each mine in every district in great Britain; and consider that their official registration and arrangement could be easily and conveniently effected in the records of the Custos, or some similar officer, of each county, to whom the chief officer of each mine should be bound to transmit them, with all their additional workings, periodically, and which should be open at all reasonable times for the inspection or copy of the proprietors, or other interested parties: and official returns of which should be regularly made to the proper department of the Government. An *organized system of mining* will evidently, in many material points, be very imperfect, indeed, will never be able to be accomplished, without *such an official registration.*

And official copies and returns made to government.

SCIENTIFIC EDUCATION OF OFFICERS OF MINES.

The mines, a vast field for the operations of science.

THE professions, the arts, the manufactures and every interest of Britain possess the great advantage of science in daily and intimate connection with all their branches and details, except those paramount to her prosperity, the mining interest; which seems almost beyond the reach of her investigations, placed in the hands of those whose early years, spent in the darkness of the mine, afford small opportunity of acquiring her enlightening and advancing principles. Consequently the system of mining in this country opens a vast field, nationally and individually, for the beneficial application of science, and requires only to be brought into familiar intercourse with her to elicit the most valuable results.

The Committee are deeply impressed with the great advantages derivable both to humanity and the mineral wealth of the kingdom, from bringing to bear the lights of science upon this subject yet so imperfectly developed. This may be stated without derogation to the great practical talent of the men that are the present guides and directors of the mines, several of whom, it is gratifying to know, are convinced of the necessity of the introduction amongst their officers of a more liberal system of scientific education. Turning a stream of science into the British mines, the Committee are aware, also militates against the prejudices of some other practical miners, who conceive it might prove injurious, by destroying a class of most meritorious men, whose experience from almost infancy is indispensable to their advantageous working, and for whom the substitution of even scientific and learned theorists, they conceive, would be a very unbeneficial compensation. The object is not to deprive the mines of such experience, but to add to experience, knowledge; to sustain or correct it by the enlightened principles of science.

The occasional visits that science has already paid to the mines have been productive of the most striking effects.

The immense results of science even partially applied.

M. Jars, the French academician, so early as 1768, after a few visits to the mines, in a memoir read to the Royal Academy of Paris, laid down the principles for their correct ventilation, that are at this day the great guides of British miners. Sir Humphrey Davy, by one examination of a single mine, was led into a course of experiment that terminated in the safety lamp: and Professor Bischof, of Bonn, by his minute analysis of the inflammable gases of the German mines, has been able to detect in them a considerable quantity of bicarburetted hydrogen (olefiant gas), which, from its explosibility at a low temperature, is of vast practical importance in the employment of safety lamps.

How little the mines have the benefit of such knowledge at the present time, with the exception of a very few honourable instances amongst their directors, any one acquainted with their practical working must at once admit.

In their daily application of the great modern-discovered power with the most gigantic engines of Britain, they are ignorant of steam, mechanics, and mathematics: opposed and sometimes defeated by the pressure and force of water, they know nothing of hydrostatics or hydraulics: their profession consisting of the extraction of minerals, they are unacquainted with mineralogy, metallurgy, or geology: existing by the correct operation of currents of air, they scarce have heard of pneumatics: and standing continually within the range of a vast laboratory of nature, whose operations are daily producing death: they still continue ignorant of chemistry.

French council of mines.

Greatly to the honour of France, she has preceded Britain upwards of half a century in an enlarged education for her officers of mines. Even during the disturbed times of her revolution, she called into existence a COUNCIL OF MINES, at the recommendation of the distinguished chemist, Fourcroy, which has been stated by the French Government to have had the happiest effect on their mines.[x]

M. Sage, a most distinguished member of this Council, first founded the School of Mines.[y] And Napoleon, in 1810, by the instruction of Count Montalivet, his Minister of the Interior, directed that the pupils of the Polytechnic School should also be instructed in the theory and practice of mines, by *experienced* and *practical* professors.

"L' administration dirige, sous l' autorité du minister de l' interieur des écoles établies en vertu des décrets imperiaux. Là des éleves sortis de l' ecole polytechnicque, et dejà forts dans diverses parties de sciences, sont instruits dans la *théorie* et dans la *pratique* de l' art des mines sous des professeurs habiles et des praticiens expérimentés.

"Les éleves ne sont admit au grade d' ingenieur qu' apres des examens séveres et la certitude acquise qu' ils ont les connoissances necessaires; ils sont alors employés sous les ordres des inspecteurs generaux et des ingenieurs en chef d' abord aux etablissemens rationaux dépendans des écoles; ensuites ils sont répartis dans les divisions departementales, pour le service de l' administration générale."—Sect xiii. De la surveillance administrative.

School of mines.

Every successive French government, since the period of their revolution, seems to have been more and more strongly impressed with similar views. In 1816 a Mining College was instituted in the heart of their coal district at St. Etienne, near Lyons; and the present King of the French in 1831 reinforced it by new and salutary regulations which, while most humiliating from the disgraceful contrast, afford useful hints for the establishment of an improved British institution.[z]

The French School of Mines is properly established in their chief coal district, that the pupils, who are taught at the expense of the government, while they continue their studies, may *practically* apply them to their profession.

In that school is taught geology and mineralogy, with the knowledge of essaying the different minerals, mathematics, mechanics, plan drawing, &c.

Pupils cannot be admitted under 15, or over 25 years of age: an examination takes place annually of their progress, and certificates are given of proficiency and good conduct on leaving the school.

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[x] Motifs du projet de Loi sur les mines, adopté par le corps Legislatif de France en seance du Avril, 1810.—Premiere partie.

[y] Motifs du projet du loi, 21 April, 1810.

[z] The unceasing attention of the French Government to the advancement of their mining interest, may be seen in the following note from Sir Charles Lemon, Bart., to the Secretary of the Shields Committee:—

"SIR,—I return your paper and am very much obliged to you for having given me the use of it" (it was the ordinance of 1831 of Louis Philippe). "I have made a translation of it; and should the school proceed, many of its provisions will be applicable to our purpose. *It so happens that I had with me yesterday a young man who was educated at the school of St. Etienne, and who has been sent over by the French Government to visit the mining districts of this country, and study our system of machinery.*"

I have the honour to be, &c. &c.,

October 30, 1840.

CHARLES LEMON.

By article VI. of the same ordinance, a class is created for working miners, or for those destined for that profession. Certificates also to be delivered to them at the termination of their studies.

Egypt.

In Egypt there is a minister and council of public instruction; and the Pacha established a Polytechnic School in 1834, which in 1838 had 235 pupils. In this school there is a mining department, in which the following courses are followed by the pupils:—

1st. *Industrial chemistry*, applied to the manufactures, raw material, and to useful objects found in or imported into Egypt; the pupils to manipulate and personally visit the manufactures. 2nd. *Mineralogical and geological courses*, travelling to the mountains and taking other journies. 3rd. *Machines and management of mines*. 4th. *Drawing of machines, furnaces, quarries, construction of models, &c.* 5th. *Manufacturing of tools and turnery*. One year after finishing these courses, to be employed in travel, work in the manufactures, examination of mines, &c.[a]

All this at the cost of the government. And that is barbarous Egypt in the nineteenth century, under the government of a Turkish soldier, while christian England, at the head of the civilization of the world, her material interests bound up in her scientific knowledge, cannot boast of a single institution competent for such objects, or, in the most distant manner, to be compared to that of Egypt.

Sir Charles Lemon's attempt to found a mining school in Cornwall.

Highly to the honour of Sir Charles Lemon, he was the first in Britain, about two years ago (1840), to attempt to institute such a school for the metallic mines of Cornwall,; and proposed to endow it in the most munificent manner, with a site for a building, £500 building fund, and not less than £10,000 at his death. In a communication from him, dated October 9, 1840, to the Committee, he states:—

His communication to the Shields Committee.

"The government have not yet been applied to for any pecuniary assistance; their sanction being given only to the form of education, and the Dutchy having consented to the tax on the produce of the mines. It is not intended to restrict the school or college to natives of the country; but to require of strangers a contribution proportional to the share of each pupil in the benefit of the tax derived from the mines of Cornwall. The nature of the education will be on the plan already experimentally in practice. That is, *mathematical, mechanical,* and *chemical;* with a course of *mineralogy and geology, and practical surveying*. We have lately had an examination on the two former subjects, and I enclose an examination paper. The result has been highly satisfactory. The position in which the matter now stands is that my proposal is before the county, and I shall collect their decision at the mining meetings about the middle of November. In the mean time I shall publish my plan for the government and conduct of the school, which will be somewhat in the following form:—That 20 persons shall be elected as governors, by 20 mines contributing the largest sums to the maintenance of the Vice-Warden's Court. That they shall elect a rector. That they shall appoint a council of five to prepare plans for the establishment of the school, and receive proposals for the buildings; and that after the school is established they shall form a council of advice, to whom the professor may refer in the absence of the general assembly of the governors. That for each £10 contributed by each mine, such mine shall have one nomination to the school, and so on: and that smaller mines may combine to make up the sum of £10. That those pupils appointed by the governors, or by any other mode than the nomination of the mines, shall pay a certain sum in addition to the fees paid by the students from the mines. That the salaries, &c., shall be provided for by a tax of *one half-farthing* in the pound sterling of value in all *metallic* minerals; and that the duration of the act shall be 12 years. A mere outline, but more particularly described, is all that I intend to submit to the county at present; and to act by means of the governing body in the preparation of details. I shall be happy to communicate with you when we are in a more forward state; and your offer of the French laws, if more than I now possess, will be very acceptable."

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[a] See Dr. Bowring's Report on Egypt p.p. 127—129, &c.

"An absolute majority," however, of the mining adventurers of the county having shewn themselves indisposed to accept the proposition of Sir C. Lemon, in December of that year, he announced their determination and his regret at the necessary frustration of his magnificent project: and so Great Britain, the country of splendid national institutions, still continues to leave her mines, her most important interest, the exception to her fostering care.

This is the more to be regretted as it is a matter so easily, so economically accomplished, and which the Committee are willing to believe has hitherto only been neglected from the want of a just and correct estimate of its value.

The course of education necessary for officers of mines.

The Committee are strongly impressed with the conviction that every *viewer* and *under-viewer*, (or the chief directing and superintending officers of mines, by whatever name they are known,) before they can be legally employed in such onerous and responsible situations, where lives and property are so extensively concerned, like medical men and navy officers, should be specially educated for their profession. In fulfilment of which, the Committee conceive that a competent knowledge of the following branches of study, as a preliminary to any official charge, is indispensable:—

MATHEMATICS AND PRACTICAL SURVEYING,
MECHANICS,
HYDROSTATICS AND HYDRAULICS,
PNEUMATICS,
CHEMISTRY,
MINERALOGY,
METALLURGY,
AND
GEOLOGY.

To complete this professional education by a course of PRACTICAL ENGINEERING AND MINING *in some fitting institution in the heart of the mining district.*

Certificates, not of examination, unless the student himself may desire it, but of having *creditably attended* complete and proper courses of such studies at one or more of the Royal Colleges or legal Universities of England, Scotland, or Ireland, to be held by each aspirant, and to be deemed sufficient.

It is fortunate for the coal mines that a valuable institution already exists in the north, with machinery in operation, which, by being somewhat extended and a practical engineering and mining professor appointed, would fully accomplish, if legally sustained, this great desideratum.

University of Durham.

The University of Durham, situate in the very centre of the great coal mining district, and easily accessible from all directions, is already adapting itself to its position, and encouraging, by affording facilities to, a better system of education amongst the directors of mines.

Professor Chavalier on the education of officers of mines.

Impressed with the advantages it possessed, the Committee held by appointment a conference with Warden Thorpe and the Senate of the University upon the 24th February, 1841, to ascertain its adaptation for the purposes of a mining school, and what modification or extension, if any, might be required; the result of that interview was in the highest degree satisfactory. An extract of a letter from Professor Chavalier, will clearly explain the University's position in those respects:—

"In consequence of the wish which you expressed at your late conference with the Warden and Senate, to be informed how far the course of education for students in civil engineering and mining in the University of Durham, is capable of being extended, so as to be available for the objects which you have in view, I have the honour to send you a brief statement of that course of study. The class of students in civil engineering and mining was opened in January, 1838. The full course of study occupies three years; but *certi-*

ficates of competency, in particular subjects, may be obtained after a shorter time. The following are the subjects included in the course of study:—

Arithmetic,
Algebra,
Euclid,
Logarithms,
Plain Trigonometry,
Solid Geometry,
Analytical Geometry,
Theoretical and Practical Mechanics,
Differential and Integral Calculus,
Dynamics,
Hydrostatics and Hydraulics,
Spherical Trigonometry and Astronomy,
Surveying, Levelling, and the Use of Instruments,
Pneumatics,
Practical Mapping and Architectural Drawing,
Theory of Perspective and Projection,
Hydrostatical and Hydraulic Instruments in general,
The Steam Engine,
Optical Instruments,
Theoretical and Practical Chemistry,
Theory of Heat,
Mineralogy,
Metallurgy,
Geology,
The French, Italian, and Spanish Languages.

The Progress of the students is tested by annual public examinations: and the extent to which the several studies are pursued will be best understood by a reference to the examination papers set at the final examination of 1840, printed in the Appendix to the Durham University Calendar for 1841. By the regulations of the University, Title vii., *persons who are not members of the University are admissable, with the approbation of the Warden, to attend any course of public lectures.* In addition to the theoretical instruction, the students are constantly engaged in the practical drawing of plans and machinery, and in levelling and surveying, under the superintendence of a competent instructor. *They avail themselves of the facilities afforded by their neighbourhood, to obtain an insight into the modes of working coal pits, and to conduct underground surveying.* They visit also, under proper inspection, the principal public works, manufactures of machinery, iron works, &c., in the vicinity, and are required on such occasions to deliver written reports. Proficiency in those branches of practical work is encouraged by prizes devoted to that particular purpose. It will thus be seen that the course of study already established for students in civil engineering and mining, requires but little modification and extension in order to meet the views of the Committee for the investigation of accidents in mines. *The principal addition required appears to be a professorship of practical engineering and mining, with an endowment sufficient to ensure the services of a person of experience and high scientific character.* * * * * The University of Durham, by having been the first academical body to establish a class of civil engineering and mining, has given full proof of its anxiety to supply an acknowledged deficiency in the system of general education, and it is still willing to co-operate further in order to effect an extension of its plans."

Professorship of practical engineering and mining.

With the addition of a chair of practical engineering and mining, and unrestricted permission on the usual terms, for young officers of mines, having already commenced their profession, to attend the lectures of this and any other of the requisite scientific courses, the Committee consider that the University of Durham would offer great and peculiar facilities for the attainment of this important object.

For practising the profession of an engineer of mines, the Committee then deem it necessary that a sufficient course of *mathematics and practical surveying, mechanics, hydrostatics and hydraulics, pneumatics, chemistry, mineralogy, metallurgy, and geology,* should be received at any of the Universities, from which should be obtained certificates thereof, before the admittance of the aspirant for the completion of his professional education, by a course of *practical engineering and mining* at the University of Durham, whose certificate should be imperative, before permission to assume this responsible situation be accorded: at which latter institution, the student now entering his profession, or having entered it and been practising it from boyhood, from which he had snatched a season or two for his studies, could, at the same time, still pursuing it, be instructed in the right application of his previous scientific acquirements, by a scientific practical teacher; who, in addition to such knowledge, with the history of mines, would be capable of expounding to him the numerous plans of mining in all their various branches previously and now in existence, not only in Britain, but in other countries, and visiting occasionally with his students the neighbouring mines to illustrate his views and enforce his objects. Thus would mining be elevated to a certain, scientific profession, with all the appliances of the existing knowledge and experience of the day, instead of the rude, uncertain, unsystematic, and dangerous art which now it is.

For the *metallic mines,* of course, some other more convenient locality would have to be selected for the seat of their practical mining professor; and probably the situation of the lately contemplated institution in Cornwall would afford a favourable position for that department of mining.

In the contemplation of such an important change, it would, of course, be proper and most conducive to its beneficial operation, that the present officers of mines should in no manner be affected by it.

In recommending the establishment of a proper scientific education for the officers of mines, the Committee deem its evident advantage, and indeed necessity, so apparent, that they have thought it quite supererogatory to adduce any lengthened argument in its support. They have endeavoured briefly to point out and facilitate what they consider the simplest, easiest, and most economical mode of effecting it, consistent with the existing learned institutions and their machinery now in operation, which only require a legal enforcement and a very trifling additional expense in a single college to produce the full result now so anxiously contemplated.

Upon the Government of the country properly devolves the regulation and enforcement of this beneficial change; and the Committee feel satisfied, that as far as they may be permitted to judge, no measure which could be adopted relating to the mines, would be so advantageous to humanity or the mineral wealth of the kingdom.

When several learned and scientific societies, whose national value is not greater or more apparent than that of the institution now proposed to be established, have funds annually placed at their disposal by the Government, the Committee would willingly persuade themselves that the same liberal and enlightened spirit will be extended to this.[b]

The facility with which a proper institution for mines may be effected.

A few legislative regulations, disturbing no existing interest, but benefitting many, and a vote of £2,000 or £3,000 a year from a great civilized and humane country like Britain, can never be deemed too much for the development and economizing of her mining resources, and the probable protection from fearful disasters of a large and useful section of her people. It is an object too consistent with her character, her interest, and her humanity, for an instant to doubt her disposition to accomplish it.

GOVERNMENT INSPECTION.

It is surprising that the coal mines of Britain, so vital to her strength and prosperity, should be left entirely to the unassisted efforts of individuals without organization or even the supervision of the state; while those of other countries, from the earliest periods, have received the particular attention of their respective Governments.

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[b] Voted by the House of Commons for the years 1840 and 1841 :—

Universities of Oxford and Cambridge,	£2000	0	0	Royal Society of Edinburgh,	£ 300
" St. Andrews,	1009	13	4	Royal Society of Dublin,	5300
" Aberdeen,	1974	0	8	Hibernian Academy,	300
" Glasgow,	1360	0	0	Belfast Academical Institution,	1950
" Edinburgh,	2580	0	0	Maynooth College,	8000

Court of Inspection at Liege in the 15th century.

The Prince Bishop of Liege, so early as the fifteenth century,[c] issued a commission on mines, which found that there had been established, from the most remote times, a court or jury of four persons, afterwards increased to seven, called "*La cour des voir Jurés du Charbonnage*," for the investigation and direction of the affairs of the mines, and that *two of its members were obliged to descend, periodically* (every 15 days), *to examine them :—" Lesquels font ensuite leur rapport, qui est enregistré, afin que là posteritè puisse voir á quelles couches ou veines les maitres des fosse ons travaillé, et quelle a été l' étendue de leurs ouvrage*."[d]

Namur.

King Philip, in the beginning of the 17th century (1635), passed an ordinance touching the mines of Namur, recognizing the rights and jurisdiction of their " Cour des Ferons," relating to their iron mines, &c.

Limbourg.

Charles, King of Spain, as Duke of Limbourg, &c., in the year 1694 issued an edict of 56 articles, on the coal mines of that dutchy.

Sweden.

And more than a century ago (1741), Adolphus Frederick, of Sweden, in a mining ordinance, refers in Article XIII., to the existence of a *Mining College* that extended its jurisdiction over the Swedish mines; and in 1757, in another ordinance, Article VII., he proclaims :—" Nous avons ordonné au College des mines, qu' il ait à faire les dispositions necessaires pour la recherche et deconverte des minerais, pour l' écoulement des eaux, pour la communication des mines, and pour l' extraction des matieres, &c."—a most important series of duties for the encouragement of their mines; which has resulted in their unsurpassed production of iron.

France.

France has also distinguished herself as a state by a careful attention to her mining interest. In a decree of 1810, Titre v., sc. 50, it is ordained :— " Si l' exploitation compromet la sureté publique, la conservation des puits, la solidité des travaux, la sureté des ouvriers mineurs ou des habitations de la surface, il y sera pourru par le Prefet ainsi qu' il est pratiqué en matiere de grande voirie et selon les lois." This perpetual watchfulness of the public interest, the security of the mines, and the safety of the workmen and the community, is highly creditable to that country; although it may be presumed that the stringency of such supervision may occasionally have raised obstructions instead of rendering facilities to their freedom of working.

Netherlands, 1817.

King William of the Netherlands, in 1817, issued a law for a central depôt of geology and mineralogy, each mine to be obliged to forward a series of specimens; and in 1825 he ordered a geological and mineralogical survey of a great part of Belgium, with plans on a scale of $\frac{1}{100000}$. The State Deputies of Heinaut in 1823, officially, in a law for the internal regulation of the mines, ordered the introduction and use of the Davy lamp in them, which has never been done for those of Britain, although here invented and believed, but erroneously, for years, to have been a perfect security against the danger of explosion; and in 1827 they commanded registered plans to be kept of their mines.

Heinaut.

Belgium, 1837: Council of mines.

The present King (Leopold) of Belgium, in 1837, instituted a *Council of Mines*, consisting of a president and four councillors, with a registrar. " Le counseil pourra reclamer le concours des ingenieurs des mines, losqu' il le jugera convenable." He also formed a Royal Commission in 1836, for examining into the comparative and absolute safety of the Upton & Roberts' lamp; they went into a general examination of safety lamps, and only reported, which they did very ably, in 1840, after persevering in their investigation for upwards of 4 years.

British Scientific Commission.

The following opinions of practical men and others with respect to a Scientific Commission in Britain have been expressed to the Parliamentary

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[c] Anno 1487.

[d] Notice de la Jurisprudence du Pays de Liege Concernant les mines de Charbon de terre ou Houille.—Appendix to Voyages Metallurgique, par M. Jars, 1774.

Committee in 1835; but a commission so constituted, without power to enforce their recommendations, the whole history of mines declares to be useless.

Mr. George Johnson, viewer, thinks "an investigation by scientific men in the coal district would be of much more importance than it can possibly be in a distant place, or at their own homes."—(1,383.)

Mr. Buddle also thinks that men of science visiting the mines would be useful, for he does not conceive much is to be expected from pitmen. "He does not think that they are the persons likely to discover any new light; he would rather look to some person of genius or science, who is not an immediate collier; and he thinks it is more likely that something might be elicited in that way than by those going on daily in the workings of the mine: the greatest improvements, he says, have been made in most businesses by people not immediately connected with them."—(2,509–2,510.)

When Mr. R. Smith is asked if he would approve of a Government Commission of chemists, geologists, and mechanics? He answers, "most highly; and he thinks nothing is wanted in this great mining country more than that is. He hopes another year will not pass without its taking place. The mines now give the great return of the kingdom—it is a mineral country from one end to the other."—(3,836.)

Dr. Pereira also concludes that a Government Commission would be desirable:—"1st., for the sake of humanity; 2nd., for the interests of the coalowners; and, 3rd., for the advancement of science."—(3,976.)

The appointment of such a scientific government commission might perhaps prove useful in laying down the bases of operation of a future permanent legislative jurisdiction and government inspection, but it is to be feared would be entirely inoperative for producing any direct material change in the system of the mines. The valuable information of the Parliamentary Committee of 1835 has remained entirely, as far as the Committee can ascertain, unemployed and unadopted to this hour. Practical men of any profession, prejudiced by habit and education, in their existing systems, will not, without the strongest influence, adopt even acknowledged advantageous change. Even the learned and enlightened in all ages have been known to oppose violently the advance of discoveries of science, although touching no interest of theirs and inducing no expense to them, but simply because they implicated previous error or affected foregone conclusions. How much more then are the less educated and the more interested likely to oppose every change?

While the Committee recognize with respect the full enjoyment of private rights and mercantile freedom, the springs and sources of the vast commercial operations that so pre-eminently distinguish Britain, yet they cannot but observe that a modified supervision of the State to secure the public interest, is perfectly compatible with them, which will facilitate at the same time the extension of individual advantage.

From the difficulty with which in general officers of mines adopt improvements, and the habitual disinclination of practical men to advantageous change, it appears only a legitimate duty of the State, considering her relative position, to take the initiative without obstructively interfering, to press every amelioration and useful improvement upon their full and fair consideration, for the advancement of the interests of society and the preservation of life, so deeply involved in the question.

Influenced by such considerations the Legislature has already been induced to authorize a continued government inspection of railways, and has interfered for the benefit of society with the principles of individual rights and freedom of trade, in the practice of medicine, law, innkeeping, &c. Therefore this Committee cannot but feel assured that, on similar principles, a modified public supervision and controul over mining operations, which implicate so largely the prosperity of the country and the safety of many of the people, are equally just and reasonable.

Scientific practical inspectors.

For the effecting of a proper government supervision, all that would seem necessary are two or three qualified practical inspectors, to pay frequent visits to the different mining districts, and descending the mines to examine them and make such suggestions as they may deem important or essential; and the directors of the colliery failing or refusing their adoption, then the whole matter to be referred to the government, or other competent authority or court, who, on hearing the merits of the question, should have power to order, under a penalty, their complete or modified execution.

Such inspecting officers would aid greatly in bringing the whole mining system, with the co-operation of the better education of the young mining officers, into the best condition that the peculiarities of the various districts are capable of receiving; and so the country and humanity would be largely benefitted by the results.

MEDICAL TREATMENT AFTER EXPLOSION.

If, notwithstanding the measures recommended, or others that may be suggested, which are likely to prevent the recurrence of explosions, they be not speedily or only partially adopted, and such an explosion should unfortunately occur, the Committee deem it proper to explain the condition in which more than three-fourths of the men meet their deaths, so that, if possible, some more effective medical treatment than that now practised, in which scarcely even a single case has been successful, may be discovered and established.

Errors on the nature of after-damp.

There have been considerable misapprehensions as to the exact nature of explosions in mines, the proportionate quantity of gas which creates them, and the products after explosion. A brief explanation of these points, supported by scientific evidence, will be of some importance, as bearing on such medical measures as may be attempted to obviate the miserable consequences.

The explosive atmosphere of mines then consists most generally of the light carburetted hydrogen gas which can only go into that state when a proportion, according to Davy and others, of from 7 to 25 per cent. of the gas is mixed with atmospheric air, which also contains usually at such a time a small portion of carbonic acid gas and free nitrogen.

Its analysis.

If a greater quantity than 25 per cent. of the light carburetted hydrogen is contained in the mixture, then it will not explode, owing to the air not affording sufficient oxygen for combination with so large a proportion; and when less than 7 per cent. of gas, it is too diluted and diffused to enter into instantaneous combination and explosion. About 12½ per cent. of the gas, or, according to Sir Humphrey Davy:—

1 vol. light carburetted hydrogen, and 7 vols. atmospheric air,	Are a mixture of the most explosive power.
Light carburretted hydrogen being composed of 2 vols. of hydrogen, and 1 vol. vapour of carbon,	When mixed with 7 vols. *atmospheric air,*
Composed of 4 vols. nitrogen, and 1 vol. oxygen,	

and exploded, as we have seen in mines, by the flame of a lamp, candle, gunpowder, a vivid spark or strongly heated wire, expands probably at least 3½ times its original bulk and forms water, or watery vapour, by the 2 vols. of hydrogen, of the light carburetted hydrogen entering into combination with 1 vol. of oxygen of the air, and much of the remainder of the vols. oxygen forming carbonic acid gas with the vapour of carbon, leaving a large proportion of the nitrogen free.

This explosion will then leave as its results, *which are the after-damp, more than two-thirds nitrogen,* and under no circumstances more than *$\frac{1}{10}$th carbonic acid gas,* from the incapacity of the air to supply a larger proportion of oxygen to form it; there will be also a portion of aqueous vapour, and perhaps, from the explosion and its motion, a small quantity of atmospheric air, or other unexploded air of the mine.

This *after-damp* is then formed of

8 vols. of nitrogen,
2 vols. of aqueous vapour, and
1 vol. of carbonic acid gas;

The relative position of the products.

and notwithstanding the doctrine of the diffusibility of gases, these different products are, in their positions in the passages of the mines, still affected by their particular specific gravities, and, in those gigantic laboratories, will be found existing in the lower or higher regions according to their relative weights. Whether the absence of the sun's rays, the operation of a sufficient body of the atmospheric air, or the want of successively applied surfaces of the latter, as in its action on the earth, be the cause of this apparent exception to the law, it is perhaps without further investigation difficult to say,—but there is no doubt that the light carburetted hydrogen is always found floating in masses in the higher parts of the mines, and the carbonic acid gas in the lower, as their specific gravities would indicate.

Now the *two-thirds* nitrogen, forming so large a proportion of the *after-damp*, from its specific gravity (0·9722) will be found filling the upper and middle regions of this mine atmosphere, while the carbonic acid gas, forming about $\frac{1}{10}$th of it, will, from its specific gravity (1·5277), take its place at or towards the bottom of the passages, and probably in great strength will extend upwards little more than 6 inches. Hence, it may be inferred that when the men, after explosion, if not struck down at once by it, attempt to leave the mine through an atmosphere of after-damp, they are at first rendered partially insensible by the nitrogen which has been substituted for atmospheric air, and then fall into a still more deleterious region, in which they meet with a large portion of a positive poison (the carbonic acid gas), and it having been inhaled to a small extent, they pass rapidly into a state of asphyxia, owing to the state to which their systems have been previously reduced.

Whether it may not then be doubted, that the carbonic acid gas, which is invariably looked upon as the sole cause of destruction in after-damp, has not an extensive co-operation in the uncombined nitrogen in aid of such results, seems a question that properly arises from the foregoing analysis and statement.

And if the destructive effects are considered as the combined action of the nitrogen and carbonic acid gas, or rather the previous effect of the first, producing incipient insensibility and incapacity of voluntary action, followed actively to their completion by the latter, it will probably aid in leading to precise and correct medical views on this subject, which the uncertainty of the cause has hitherto somewhat prevented.[e]

Practical inferences.

Two practical results are thus plainly indicated:—1st. That as the lamps are *instantaneously extinguished* where carbonic acid gas is abundant, and burn with a dull red flame as they approach its confines; then, on these indications, *the miner is warned immediately to retire, as flame is here extinguished before life;* but when there is *a large admixture of nitrogen,* the *lamp continues to burn as in sulphuretted hydrogen, even when the miner is struck down, life being in the latter case extinguished before flame.* This was fully verified in the St. Hilda Pit explosion in 1839; but in every case any alteration in appearance of the flame ought instantly to be attended to.

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[e] Davy found an animal live, though only for a short time, with 100 parts azote, 14 carbonic acid gas, and 7 oxygen.—(Researches on Flame, p. 37.) Bischof conceives air irrespirable if it contains more than half of the carbonic acid gas to oxygen; and that atmospheric air, with $\frac{1}{10}$th carbonic acid gas, will, with difficulty, for a time support respiration.—(Memoires sur l' aerage des mines, Ch. V.) Professor Graham, of London, after an explosion with certain supposed proportions of gas and atmospheric air, conceives, after the expansion, a fresh intermixture of the latter, and infers it may possess this composition:—

Oxygen,	14 vols.
Carbonic Acid,	7 ,,
Nitrogen,	79 ,,

"Yet such an athosphere, he adds, would be powerfully narcotic, and soon prove fatal to persons immersed in it."—(Extract from a communication of Professor Graham to the Committee, Nov. 14, 1840.)

This was strongly sustained, as has just been stated in the appearance presented in St. Hilda Pit explosion, when, in less than two hours after it occurred, the Secretary of the Committee beheld the men in the passages fall down insensible, while their lamps continued to burn in the same place with a steady though imperfect light, indicating nitrogen ; and a sort of instinct, led the few men around to sit down for relief, asserting that the higher region of the passages was most destructive, and which, on following their example, was found to be the fact; the change soon affording relief from sickness and intense head-ache. Sitting in these vitiated passages, which are about 6 feet high, would bring them to inhale the middle atmosphere, which would probably contain less of nitrogen or carbonic acid gas than the upper or lower portions, thus sustaining the foregoing reasoning in all its parts.

2nd. That asphyxia, arising from nitrogen and completed by carbonic acid gas, might probably indicate a different system of medical treatment.

Dr. Pereira to the Committee.

Dr. Pereira, in a letter to the Committee, of the 10th November, 1840, agrees with the above stated products of explosion of the reacting proportions in those quantities specified, though he adds, " he suspects that we were disposed to underrate the injurious effect of the carbonic acid gas of the after-damp." Professor Graham, of London, also states—" The representation which you have given of the composition of the explosive atmosphere of coal mines, and of the products after an explosion, are, I believe, substantially correct ;" and Professor Hope, of Edinburgh, supports the views of the Committee, by his remark to them, that " the opinion is certainly an erroneous one that the deleterious nature of the after-damp arises from the presence of the carbonic acid gas alone."

Professor Graham.

Professor Hope.

It is gratifying to the Committee to be able to give the following communication from the eminent modern writer on Poisons, Professor Christison, of Edinburgh, upon this question. It is addressed to one of the Secretaries of the Committee, and well developes the professional nature of the subject :—

" Edinburgh, 24th June, 1842.

Professor Christison to the Committee.

" Sir,—I regret very much the delay which has taken place in my reply to your letters respecting the accidents occasioned to workmen in mines from explosions and choke-damp. Your letter of the 8th May, reminding me of my promise to communicate my views to you on this subject arrived while I was in London ; whither it was not dispatched for some time, as my stay was at first expected to be short. Business having detained me much longer than I anticipated, your letter was at length forwarded to me. But while in London, I could not have access to your previous letter, containing the facts connected with the subject, nor to the sources of information I wished to consult. * * * * I am afraid my answer to yours may arrive too late for your purpose ; but I trust you will believe I have done what I could to comply with your wishes. I understand your queries to relate to those cases only in which mines are exposed to the noxious gases which take the place of atmospheric air after the explosion of carburetted hydrogen, and not to those in which carbonic acid is breathed without previous explosion. If I am right in so thinking, and in assuming that the remarkable instances where a peculiar odour, sudden swelling of the body, and very early decay are observed, occur in the former circumstances only, then it appears to me that the peculiarities in such cases may be accounted for by reference to other causes besides the nature of the gases that are breathed. All the investigations hitherto made into the action of the irrespirable gases seem to prove that nitrogen gas is merely a negative substance in respect to respiration, and that its effects, when breathed, are undistinguishable from those of simple obstruction of the breathing, especially when that obstruction is gradual, not complete. Consequently it is not probable that the nitrogen in the foul air breathed by the miners has anything to do with the peculiar phenomena you describe as characterising the cases of the miners who die after explosions of fire-damp. The carbonic acid is well known on the other hand to be a positive poison of the narcotic kind, as, indeed, you must be well aware ; and it has been fully ascertained that a less proportion than that stated by you ($\frac{1}{10}$th) will speedily prove fatal even when mixed with atmospheric air. The question is, whether it will cause the appearances after death you have described in your letter to me. I do not find these appearances mentioned in any of the numerous cases I have hitherto had occasion to consult of death from the inhalation of carbonic acid in various forms. Consequently the idea entertained by yourself and your friends, as to there being something peculiar in the nature and causes of the death of miners after explosions, is probably correct. In cases of death, by slow obstruction of the breathing, rapid decay is sometimes observed, but not so rapid as you describe in regard to the cases of miners. The phenomena approach nearer those which characterize death by lightning than any other mode of death. It occurs to me as possible, that the peculiarity adverted to may be owing to the effect of the explosion in causing concussion. I do not see how otherwise the circumstances of the cases can be accounted for. It is possible, however, that you may be in possession of information which is at variance with this supposition.[f] A more precise acquaintance with the nature and causes of such accidents would, without doubt, be of service in directing medical men to a judicious mode of treatment. At the same time I cannot help surmising, that the cases you describe are of a kind in which no treatment is likely to be of material service. The phenomena you mention, viz., the indications of premature putrefaction, show that most serious disturbance is caused to the functions of the body generally, and that the properties of the blood are in all probability irretrievably altered. A more minute and professional account of the progress of matters until dissection, and of the appearances found within the body on anatomical examination, would throw light upon this question. Meanwhile, it is difficult to say what line of treatment is most likely to prove serviceable. Were the accidents merely cases of poisoning with carbonic acid, the treatment would be more frequently successful than it appears to be. At all events this treatment is so well understood now that I need scarcely mention it. Dashing cold water over the head and neck; the application of the ordinary internal and external stimulants; occasionally moderate depletion of blood; artificial inflation of the lungs; and sometimes galvanism, constitute the leading remedies in such cases. Until I have a more minute professional description of the cases of miners after explosions, however, I cannot venture to say that similar treatment is equally applicable to them; and, on the whole, I repeat that the particulars you have already related to me, would lead me to form a very unfavourable opinion as to the probability of any treatment proving successful. I ought to have observed, that it is not quite clear to me from your description, whether the individuals, whose cases you describe, shew any signs of lingering vitality after they are found; but I take it for granted that they do. On this and other medical points, it would be obliging if you could furnish me with detailed professional information; for I have no where seen a precise and minute account of the effects of explosions in mines on the body.

"I am, &c.,

"R. Christison."

Here at present the Committee may leave the question of medical treatment after explosion until an opportunity is afforded of minute professional investigation; with, however, the addition of a few simple rules, translated from *an instruction* of the French Government of 1813, procured from their highest medical authorities; and which were to be the mode of procedure of the professional men, who, according to a decree of the same year, were to be provided by the owners, for the service of their workmen.[g]

It will be altogether unnecessary, and would be foreign to the proper duties of the Committee, to say a word on the medical treatment of the ordinary and well understood accidents of the mines—as burns, wounds, and bruises—which have already the first professional knowledge regularly applied to their relief: and *which can only be expected to be reduced in number and extent by the application of such improved modes of mining as have been suggested, and which may be secured by the better education of the mining officers, by government inspection, and the adoption of a system sanctioned by the unerring dictates of science and experience.*

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[f] Men in a distant part of the workings, to whom even a knowledge of the explosion has not extended, till its effects have been felt in the vitiated air or interrupted ventilation, or men fresh from day, have undergone nearly similar symptoms and effects without exposure to the influence of the concussion.

[g] Decree of Napoleon, January, 1813.—Titre III., Art. XV.

French "Instruction."

French medical instruction.

"Upon the character of the accidents to which the working miners are exposed, and upon the nature of the aid which ought to be administered to them when these accidents take place.

"The numerous accidents to which the miners, and the workmen in the metallic mines are exposed, render necessary the publication of a short and clear instruction upon the nature of these accidents, and the remedies which they require.

"Asphyxia.—The miners are exposed to asphyxia when the circulation of the air is not made with sufficient activity, when the substance which they extract exhales a great quantity of deleterious gas, when they imprudently penetrate into ancient and abandoned works, and when the combustion of hydrogen gas is made too rapidly; and, they might have added, the air thereby deprived of its oxygen.

"The symptoms of asphyxia, always easy to be known, are the sudden cessation of respiration, of the pulsations of the heart, of the action of all the sensitive functions; the countenance swollen and marked with reddish spots, the eyes become protruded, the features are decomposed, and the face is often livid. * * * * It is necessary to succour an asphyxied person with the greatest promptitude, and to continue the remedies with perseverance as long as there is not a certainty that life is completely extinguished.

"The best and the first remedy to employ, that in which the greatest confidence ought to be placed, is the renewal of the air so necessary to respiration. In succession:—

"1st. You will promptly withdraw the asphyxied person from the deleterious place, and expose him to a good and pure air.

"2nd. Undress him, and throw on the body effusions of cold water.

"3rd. Endeavour to make him swallow, if it be possible, cold water slightly acidulated with vinegar.

"4th. Clysters should be given, two-thirds of cold water and one-third vinegar; afterwards to be followed up by the administration of others with a strong solution of common salt, or of senna and epsom salts.

"5th. Attempts should be made to irritate the pituitary membrane with the feather end of a quill, which should be gently moved in the nostrils of the insensible person, or stimulated with a bottle of volatile alkali put under the nose.

"6th. Introduce air into the lungs, by blowing with the nozzle of a bellows into one of the nostrils, and compressing the other with the fingers.

"7th. If these means do not sufficiently produce the effects which are expected, the body of the asphyxied person preserving its heat, as that generally occurs for a long time, it will be necessary to have recourse to blood letting, of which the necessity will be clearly indicated if the face be red, the lips swollen, and the eyes protruding. Blood-letting from the jugular vein will produce the speediest effect: in default of drawing it from that place, it should be made from the foot.

"8th. For the last resort, an opening should be made in the trachea, and a small pipe introduced through which the air should he pressed by the aid of a little bellows.

"It is necessary to apply these various remedies with the greatest promptness; the later they are in being employed, the more there is to fear that they will not be efficacious; and as death does not certainly appear for a long time, they ought not to be discontinued, but when it is clearly confirmed. The absence of beatings of the pulse is not a certain sign of death. The want of respiration is not sufficient to constitute it. Neither ought to be regarded as dead persons, those whose breath or pulmonary transpiration does not bedim the brightness of a glass; nor those of whom the members are stiff and which appear insensible."

The Committee have given these brief instructions that some of them may be judiciously practised, instead of the injurious plans sometimes adopted, (such as placing the face of an asphyxied person in a hole of the earth), until the arrival of a medical practitioner, who will then find the patient prepared uninjured for his professional skill, and his object facilitated, not obstructed, by the previous treatment which has been applied.

SUMMARY OF GENERAL CONCLUSIONS.

Summary of general conclusions.

The Committee deem it proper to collect and concentrate the *conclusions* which they have deduced in the course of their investigations; and refer to the proper heads of the Report for the detail and premises by which they are supported and have been elicited.

1st.—Safety Lamps.

The Committee find, after the most minute investigation and careful attention and experiment which they have been able to devote to this branch of their subject, that no mere Safety Lamp, however ingenious its construction, is able to secure fiery mines from explosion, and that a reliance upon it is a fatal error, conducive to those dreadful calamities which it is intended to prevent.

The Committee further find, that the naked Davy lamp, without a complete shield of glass or other material, is a most dangerous instrument, and has indubitably been productive of those accidents in mines against which it is too confidently and generally employed, at the daily imminent risk of producing such calamity.

The Committee also further find, that the best description of lamp to be employed in fiery mines, is one on a perfectly new principle, that of an *improved British and Belgick lamp, in which the supply of air is derived entirely through the upper part of the construction, over the glass shield,* which, from the greater diffusibility of the explosive gases, operated on by the temperature of the lamp, down whose heated interior they have to descend, chiefly enables the atmospheric air to visit the flame: but, that notwithstanding this improvement, the utmost attention must be continually paid to the condition of even these lamps, and still more to those of other descriptions; that the gauze must be examined daily, and every part of the apparatus be ascertained to be perfect; that the workmen must be warned never to continue in an inflammable atmosphere with their lamps overheated by the increased flame; and that instead of being impressed with the idea that these lamps are absolutely safe instruments, they should be convinced that they are only comparatively safe, and that contingencies may easily arise in which even the best constructed may be productive of danger and explosion.

2nd.—Ventilation.

The Committee find, that from erroneous conviction or other less defensible cause, securing safety in mines by lamps has been beyond all reasonable bounds relied on; while the far more important and safer system of ventilation has been comparatively neglected.

That the condition of the ventilation of the northern mines, which abound above all others with explosive gas, is of the most dangerous description,

Summary of general conclusions.

sometimes at a rate in the galleries not exceeding 2 feet; and in some of the most extensive mines it is reduced so low as $1\frac{1}{10}$th, 1 foot, and even ·66 of a foot, as the average velocity of the air current, which is produced by the limited proportion of pit and shaft area to the enormous extent of the subterraneous excavations sometimes extending beyond 70 miles, where nearly 400 acres are supplied with atmospheric air by a single pit.

That this imperfect state of the ventilation in the northern mines is caused by too few shafts in proportion to the extent of underground workings; that the cost of sinking those shafts has been unduly exaggerated; and that the saving of expense from destruction of brattices, waste of ropes, injury from explosion, &c., eventually compensate for the increased first outlay on the necessary additional shafts; that only increased velocity, and diminished length of air currents, can secure against the recurrence of explosions, and that, for this purpose, one shaft ought to be apportioned to at the most 40 acres, which is much more than the proportion in the metallic mines of Cornwall, or in the coal mines of Staffordshire; often more than in those of Lancashire, and sometimes in those of the northern coal field; and that no "winning" or extraction of coal in a new mine should be allowed to be made, unless two distinct and separate shafts have been previously put down, which should be secured by act of parliament.

That for facilitating the easy passage of air without obstruction, the areas of the upcast shafts should invariably equal, if not exceed, the areas of the downcast, instead of bearing, as they now do, in many instances, a proportion of 2 to 1. This is clearly evident when it is considered that the heated products of the air, after combustion, as nitrogen, carbonic acid, &c., in ascending the upcast are expanded nearly $\frac{1}{7}$th, by the increased temperature of the furnace, from the time of their descent through the downcast and passage in the works.

That the plan and mode of ventilation by high pressure steam, recommended by Mr. Goldsworthy Gurney, the distinguished inventor of the Bude Light, as developed in his communications to the Committee, fully detailed in the Report, seem peculiarly adapted for accomplishing, at small expense and without derangement to the present system of working, a vast increased and manageable rate of current. That this power, although manageable, is almost illimitable, and can be applied to sweep the galleries with the almost irresistible force of a hurricane, guided only by the safety of the works when the men may be absent from the pit, rendering it, before their descent, pure, healthy, and safe.

That considering its power, safety and economy, facility of execution and command, ventilation by high pressure steam is peculiarly fitted for the present condition of mines, and adapted for them in every stage of their operations. That it appears one of the most important and valuable suggestions, and if fully and properly applied, preferable, as far as relates to its effects on the safety and healthiness of the mine, to any invention of modern times.

That in addition to these improvements in ventilation, the plan of exhausting the gas by drifts driven along the face of dykes which are found to dam back and accumulate the gas in great abundance, and perhaps aid in creating it, and which has flowed up through the natural divisions of the coal, *backs, slines, or cleavages*, is deserving of extensive application. That the support which the natural position and dip of coal seams, their structure and their interruption by faults or dykes, give to the suggestion of draining by gas drifts scientifically applied, borne out by extensive practical demonstration of its great utility in Warwickshire and Staffordshire, and partially in some instances in the Northumberland and Durham districts, leaves no doubt of the important advantages derivable from them, and which are the more valuable as no interruption of the slightest kind to the present mode of operating in mines, and but small increased expense will arise from their introduction; and thus there exists no real obstruction to their general and immediate adoption.

Summary of general conclusions.

3RD.—SCIENTIFIC INSTRUMENTS.

The Committee find that the variation of the pressure and temperature of the atmosphere influence the evolution of gas in a very striking manner, and that a few degrees fall of the barometer, and increase of atmospheric temperature indicated by the thermometer, are certain to be followed in fiery mines by a corresponding increase of danger, by the removal of the pressure from the pores, cleavages, and blowers in the coal, admitting a more easy ingress of gas into the galleries of the mine, and by tending to equalize the weight of the two columns of air of the downcast and upcast shafts, reducing the rate of circulation, all which co-operate to effect an increased flow of gas and a decreased ventilation, causing the mine at such time rapidly to assume a most dangerous condition.

That the necessity of those instruments is thus strongly indicated for every mine, especially the barometer; or better, as more delicate, more convenient, and more anticipatory, the *sympiesometer*, whose indicating fluid is nearly similar to that to be guarded against, the gas of the surcharged crevices of the mine, which are so many natural sympiesometers acted on by every material change of the atmosphere.

That the sympiesometer, or barometer and thermometer, are essentially necessary for every well regulated mine, and should be placed under the care of a skilful person, who ought, at the same time, in a convenient room, to have charge of the safety lamps, and that they should be open at all times to the inspection of the officers, who, by a proper attention to their indications, will be able to anticipate with certainty for hours a threatened mining storm, to make provision against its insidious approach, and render innocuous the development of its dangerous elements.

That the rude and barbarous mode of measuring the velocity of the air currents by the smoke of gunpowder or tobacco, or the regulated pace of a person by the flame of a candle acted on by a current contracted and disturbed at the point of operation by his body, are incorrect modes to acquire a knowledge of the true velocity of the columns of air through the passages of the mines, on which their safety entirely depends: that a correct anemometer, on scientific principles, would be a great acquisition to every mine, one of which might be entrusted with much advantage to the care of the lamp and instrument keeper, and placed in one of the main air currents, and another to the furnace keeper for his guidance. A mere inspection of either would enable, in an instant, an officer to ascertain the exact condition of the mine, without having recourse to a troublesome experiment, not always practicable or safe, and he would perceive whether the passages were free, the furnace or other motive power properly worked, and what the present and past velocity in his absence, of the ventilation; also at the same time indicating atmospheric changes, conjointly with the sympiesometer and thermometer.

That, also, were officers of mines properly educated for their profession, an *eudiometer* would be a valuable instrument for occasional employment, to discover, not only the comparative purity of the air in the mine, but also the exact per centage of carburetted hydrogen, flowing, under certain circumstances, into the exposed passages, thus enabling a mathematical calculation to be made of the quantity and velocity of air required to keep the pit atmosphere below the explosive point. That, therefore, the eudiometer ought not to be omitted in every well regulated mine as an instrument essential to its safety, in conjunction with the sympiesometer, thermometer, and anemometer.

4TH.—INFANT LABOUR IN MINES.

The Committee refer to this subject in their Report, which was written previous to the introduction of Lord Ashley's bill restricting the employment of boys till their arrival at a certain age. The Committee have assigned reasons

Summary of general conclusions.

for the opinion that admitting children as trappers, their first employment, at too early an age, is prejudicial to the safety of the mine, and have given recent instances where so many as 30 deaths at a blow have been caused by the negligence of a boy of nine years of age, while they consider it proper for the increased safety of mines, as well as to secure a better education and physical health to the little sufferers, to restrict the period of their descent into the mine. They have also endeavoured to show that extending the term for commencing a pitman's life beyond eleven, or at furthest twelve years of age, will be detrimental to the supply of good pitmen, and consequently will prove injurious to the amount of produce, with an increase of expense, which will fall upon the public, and on the arts and manufactures, by an increase of price, to the advantage of the foreign competitor. The Committee, notwithstanding certain arrangements of the new act, continue to retain their matured conviction expressed on this subject in their Report.

5TH.—REGISTERED PLANS AND SECTIONS.

The Committee consider that the advantage of registered plans and sections of mines, especially the horizontal workings of coal mines, is clearly obvious, inasmuch as from ignorance of the exact position of workings, old mines are not unfrequently approached by new, and have been several times penetrated by the latter, and the accumulated water with which they have been inundated, has burst forth, severely injuring or overwhelming the more recent works, and destroying a large amount of life, on one instance so many as 75 human beings.

That a regular and correct registration of the plans and sections of every mine in the several districts, with the progress of the works, and such particulars as may be of consequence to the public or future proprietors to know, are important to estimate the present capability of a continued increasing supply of the national minerals, and the best organization of which they are capable, for securing, as far as possible, their advantages to posterity.

That practical men seem perfectly satisfied of their value, and are willing to facilitate the operation of a well arranged registration, whenever the government may deem it their duty to adopt the necessary measures; and that for such purpose the office of custos, or some similar office, of each county affords peculiar facilities for a district registration, and which, at specified periods, should be transmitted to the Secretary for the Home Department, or some other proper officer of Government, to be arranged in the general mining plan and records of the kingdom.

That the attention paid to this subject by the Governments of foreign states, as shown in the Report, is an additional cause of stimulus to the adoption of a similar procedure in this country, and that from their well digested arrangements, useful suggestions may be obtained for the execution of a good organization in Britain.

6TH.—SCIENTIFIC EDUCATION OF OFFICERS OF MINES.

The Committee find that the mining interests of Britain, those paramount to her prosperity, are placed beyond the habitual investigations of science, being practically and almost entirely in the hands of those whose early years spent in the darkness of the mine, have been beyond the reach or acquirement of her enlightening principles. That consequently the scientific attainments of the chief officers of mines, the viewers or directors, and under-viewers, with a few honourable exceptions, are generally far inferior to the high responsibility of their office.

That whenever science has been brought to bear on the mines, the most beneficial results have been the consequence. That M. Jars, the French academician, from a few visits to the mines in 1764, explained the principles of ventilation, that practical miners though so deeply interested in, never could discover: that Sir Humphrey Davy, by one visit to a single mine, was led

Summary of general conclusions.

into a series of brilliant experiments that terminated in the safety lamp: that Professor Bischof has detected in examination of minal gases, a new element of danger in the employment of that lamp; and that Pereira, Gurney, Murray, Turner, Hemming, and other scientific men, by correct experiments, have demonstrated the certain explosion of inflammable gases, by similar lamps, under particular conditions, in mines which, although valuable works and thousands of lives were daily exposed to destruction by their use, were, till now, relied on by practical men with a fatal confidence; all which, had the officer of mines been sufficiently educated for his profession, might probably have been long ago anticipated; besides other dormant advantages lying hid in the mines, which require only the proper application of science to be called into existence. That as the Legislature and Government have recognised and required, in the learned professions as well as in the navy and army, a systematic professional education, before admittance to their responsibilities and duties, it seems also necessary and proper that the same principle should be extended to a profession which is so important to the best interests of the country, and involves the lives of so many of her people.

The Committee deem essential for the professional education of an officer of mines, a sufficient knowledge of

Mathematics and Practical Surveying;
Mechanics;
Hydrostatics and Hydraulics;
Pneumatics;
Chemistry;
Mineralogy;
Metallurgy; and
Geology;

which branches of science are so easily accessible at any of the learned institutions of the kingdom, and may be acquired at proper seasons by the young officer of mines simultaneously with the practice of his profession.

That at the termination of such a course of study, an opportunity should be afforded him of attending a *Professor of Practical Engineering and Mining*, in an institution of a fitting locality in a mining district, who, with the systems, modes, and practices of mining, ancient and modern, in all their various branches, would expound to the young aspirant the right application of his previous scientific acquirements.

That the Committee have found in the liberal arrangements and disposition of the Warden and Senate of the *University of Durham*, situated in the heart of the great coal district of the north, every prepared facility for the attainment of this latter important object, as far as relates to coal mining—the metallic mines requiring, of course, another locality, and the Senate have expressed to the Committee their further willingness to co-operate in a Legislative and Governmental plan, by the appointment of a *Professor of Practical Engineering and Mining.* That the learned institutions of the country, and their machinery already in operation, are then amply sufficient for this national object, so creditable to the character of the country, and so advantageous to her interests, and that it only requires an authorized arrangement by the Legislature, and a small monied grant for one additional professor in a single college, to complete the important organization.

When it is considered that by a scientific education of the officers of mines, the great objects sought to be obtained are, to enable our mineral resources to be better developed and economized, and a large and useful class of our people better secured from the fearful disasters of the mine, the Committee cannot anticipate a shadow of a just or reasonable objection to its early adoption.

7TH.—GOVERNMENT INSPECTION AND JURISDICTION.

That considering the importance to Britain of the lives and interests involved in mining, whose field of operation is placed far beyond the reach of

Summary of general conclusions.

public vigilance and ordinary investigation, and that practical men, wedded to the early practices of their professions, have a decided repugnance to change, and the introduction of new modes or suggestions in any department of their works, even though sustained by the discoveries of science or improvements in the arts, the advantages derivable from *an enlightened public jurisdiction, in a well organized system of Government inspection,* are clear and indubitable.

That such inspection and jurisdiction for securing the fullest protection to the public interests, are perfectly compatible with the private rights of property and the freedom of trade; and that the principle has already been acknowledged and acted upon by the Legislature with regard to railways, the professions, the manufactories, and some of the trades, and is peculiarly applicable to mining, unlike the former, far removed from an enlightened public investigation.

That in Sweden, Heinaut, Belgium, France, and other countries, the recognized rights of legislation and supervision of mines by the State having been productive of great advantages, afford encouragement for the admission of a similar application of the principle to Britain.

Therefore the Committee find that for facilitating the introduction of sound principles of mining, both productive and economical, and for the protection of the workmen, it is necessary to employ well-informed scientific and practical inspectors to pay frequent periodical visits to the mines, registering official suggestions and recommendations, and on their non-adoption, fully or partially, by an appeal to an authorized tribunal, such as a court of mines, or some other competent authority, which could entertain the whole question judicially, to enforce, if necessary, under certain penalties, their execution and operation: and thus would mining receive the full benefit of the advancing knowledge of the times.

8TH.—MEDICAL TREATMENT AFTER EXPLOSION.

The Committee deem this department of the subject so important, new, and complicated, that they beg to refer to it in full in the body of the Report, in which will be found an examination of the nature of the deleterious gases of mines, a valuable communication from Professor Christison, on the subject, and the official medical rules of treatment in France after explosion, which the Committee trust will aid in extending correct views on a point requiring still further professional investigation; and which, at the same time, will also prevent the rude and unskilful practices too frequently adopted after explosion, to the great, and sometimes fatal, injury of the unfortunate sufferers.

END OF REPORT.

APPENDICES.

APPENDIX (A.)

PLAN FOR VENTILATING COAL MINES, BY JOHN MARTIN, ESQ., LONDON.

Appendix A.

Mr. Martin's Plan.

Since the sitting of the Committee of the House of Commons upon Accidents in Coal Mines, so many great explosions have taken place and lives been lost, that it must have become obvious to all how constantly similar accidents will recur whilst the present imperfect mode of ventilating and working mines is pursued; and the evidence of Mr. Buddle himself fully confirms the opinion that a complete system of ventilation and drainage is essential to preserve the security of the mines. I will, therefore, as succinctly as possible proceed to explain my method of ventilation; previously, however, making a few observations respecting the "Davy lamp" which still continues in such general use. From various experiments, indeed, from Sir Humphrey Davy's own acknowledgment, this lamp is found only to be safe under particular circumstances; and I have myself seen it exploded with hydrogen gas, for amusement, at the rate of sixty times in a minute. It is not, however, my intention to speak of the insecurity of the "Davy lamp" only, as I know that the safest lamps hitherto invented maybe exploded under circumstances to which all mines are liable. The lamp which I invented some time since, was considered the nearest to safety, *on principle*, and has never been exploded in *carburetted* hydrogen, although it has been so with *pure* hydrogen. The experiments with my brother William Martin's lamp have had the same results; and Messrs. Upton & Roberts' must prove the same, as their lamp is a palpable copy of my brother's. In order to account for our lamps not exploding in carburetted hydrogen, it has been said that this gas is actually only to be found in the pit; but this can scarcely be the case, and, even if it were so, the lamps were all submitted to the same test. But there is one point which does not seem hitherto to have been noticed: it is, that *the same gas will explode* more freely where the air is purer, and this change from one state to another may at any place occur in a few minutes. I arrive at this conclusion from observing on one occasion, when I was trying the "Davy lamp" with my brother's and my own, that the former exploded when neither of the others did so; but on trying the same lamps, with the same gas, at the same place, but on another day, the whole three exploded. I then made some observations, and found that the atmosphere was much clearer, and consequently more favourable to combustion than on the former occasion; and inferring that the same principle holds good in the mines, the gas there being more or less explosive according to the state of the surrounding atmosphere, I conclude that safety lamps should be expelled altogether; for even granting it possible to obtain a lamp safe against hydrogen, where would be the security against the ten times more deadly choke damp? The result of all my experiments and inquiries only establishes my first proposition that such a thorough system of ventilation is requisite as would render it safe to use common candles to light the workmen.

I will now, without further preface, enter upon my plan for ventilating coal mines. I first propose to form a square of any size, say ½ a mile on each side, or 2 miles round the whole mine, as follows:—From the bottom of the downcast shaft, two ways should be formed running close by each other; the one to go, and the other to return, till the first half mile is attained; these ways should then turn at a right angle to the left for another half mile to the upcast shaft. The same to be done on the left hand of the downcast shaft, thus completing the square and obtaining a free current round the whole mine, from the downcast to the upcast shafts on the right, and the same on the left: the lowest end of the strata or beds of coal should then be ascertained, and a proper drain be formed. To facilitate the working of this mine, the two shafts should be commenced at the same time, and the ways would thus meet each other at the intermediate angles; the men should proceed to cut away the coal at these two corners between the shafts, and to convey it to that shaft which is nearest. Gunpowder might safely be used with this plan, as the current of fresh air would continue to sweep the face of the works where the miners are extracting the coal, and as fast as the gas comes out, it will be carried away by the ventilator at the upshaft. One set of men should be blasting and hurling the coal down, and another set be forming pillars, but no more pillars should be allowed to remain than would be sufficient to protect the two ways. The whole of the coal should ultimately be taken away, excepting the row of pillar next to the surrounding gallery, or outside way, which will be of value in protecting the drain, and likewise in working the next square mine when the old one is exhausted. As the open space behind the works becomes wider, the support being removed the roof will fall in, and close up the void; but it would be of no consequence if this were not entirely closed up, since the higher end of the goaf would always be nearest to the ventilating gallery, the hydrogen gas escaping by a short and straight line to the upshaft, and the lower end being nearest the downshaft, would allow the water and carbonic acid gas to run off by means of the great drain to the well, and be thence pumped out (*see* diagram). Thus would be obtained the shortest and straightest way to ventilate, drain, and carry

Appendix A.

Mr. Martin's Plan.

off the coal, without danger to life from explosion, or choke damp, or chance of destruction to property; without trap-doors or men to watch them; without the necessity of inducing men to work by means of a pretended safety lamp; and last, though not least, to the coal-owners, without viewers paid a heavy centage for working dangerous parts of the mine. Wherever a new mine is to be opened, it should be upon this principle, as cheaper, easier, and certainly safe; and I would suggest that, whatever the expenses of the first experiments, it is but just and fair that they be borne by all the coal-owners in proportion to the extent of their coal property, as the result would be to the advantage of the whole. It is not, however, absolutely necessary to form an entirely new mine to test the correctness of my views, as my *principle* can be applied at once to any old one; and I propose to mark out, on the working plan of the Wallsend Colliery, which shows the highest and lowest beds of coal, the method of applying my plan, and am willing afterwards to submit it to the severe and close scrutiny of men of science and judgment, and to abide by their decision, provided there is no biassed party allowed to interfere on either side. I earnestly entreat the coal-owners themselves to carefully examine the details of the plans and compare them with those now in use, for it is their bounden and solemn duty to consider and adopt whatever measures are in their power to preserve the lives and limbs of their labourers; and if not for humanity, yet for their own sakes they should do so, as the whole onus will rest with them, and not with the viewers, who are understood to be mere tools in the hands of their employers. I am aware that the coal-owners, in common with most who are not "practical men," are doubtful as to their competency to pass judgment on plans which may be submitted to them; and this strengthens my opinion elsewhere expressed as to the necessity of making drawing (especially ground plans, elevations, and perspective) a principal branch of education in our colleges and other schools, in order that our legislators may be enabled to understand and judge for themselves, without being obliged to rely on the dicta of practical men who may be incapable of judging, either from want of talent, or want of principle, the worst evil of the two; for this last too often condemns that measure which would clash with his own interest, and does not hesitate privately to adopt ideas which may be adapted to his own purposes. When I first laid my plan before the Committee upon Accidents in Coal Mines, the honourable members requested me to explain my views to Mr. Stephenson, the engineer and practical man to whom they referred the various plans. I, therefore, began by showing a drawing of Mr. Buddle's Plan of Jarrow Colliery, with my explanation of the working of the system; but when I mentioned the accumulation of foul gases in the various recesses where the pure air did not enter, he flatly contradicted me, and declared that all parts of the mine were equally ventilated. I contended that the plan was correctly drawn from that of Mr. Buddle's, the principal coal viewer in the kingdom, and appealed to the chairman, but no answer was returned, and I was allowed to be put down. However, when Mr. Buddle came before the Committee relative to the explosion of Wallsend Colliery, I took an opportunity to show him my plans. The first drawing we looked over was a copy of the plan which Mr. Stephenson had condemned, but with very different results; for upon explaining to him the same points which I had previously explained to Mr. Stephenson, I proved to be so correct that Mr. Buddle complimented me by saying, that I was the best amateur coal-viewer he had met with, &c. After Mr. Stephenson's unceremonious non-admission of my plans, I sat down to observe the progress of the inquiry, and gained a variety of useful information and practical knowledge during six weeks close attention to the evidence of numerous scientific men, whose views I was gratified to find fully confirmed my own, and enabled me to mature and perfect my plan.—[Mr. Martin here makes some severe remarks on an error that had been detected in a plan of a gentleman connected with the northern mines, but as it does not appear necessary to the elucidation of his own plan, it has been at present omitted.]

It has been repeatedly asked why this simple and efficient plan has not been adopted, or at least tried, since it is applicable with perfect safety to the present mines in their half-unfinished state, as it is obviously cheaper, being without the drawback of expensive trap-doors, stoppings, destruction of horses, or allowance to widows and orphans? My answer is, that the coal-owners do not trust to their own judgment, but apply to interested or prejudiced viewers and practical men of their own choice, in the supposition that Mr. Martin, not being a '*practical man*', can know nothing about it: but I have first-rate practical men, and men of the highest distinction in science (Mr. Smith and Dr. Birkbeck for instance) decidedly in favour of my proposition.

There are, however, reasons for persisting in the use of the Davy lamp instead of ventilation. It appears that before the introduction of this lamp each man used to have 20 guineas bounty for the year, for working in a mine considered dangerous; but when the lamp was invented it was placed in the hands of miners, and the bounty withheld, thus effecting a saving to the owner of £20,000 in premiums to 1,000 men. Another reason is, that before the introduction of the lamp the men refused to work many parts of the pits, and a large and important proportion of the coal was thus absolutely lost to the owners. Thus has this horrible system been maintained, for the viewer himself has no small share of the profits, as I am informed, he receives as much as 15 per cent. for working dangerous parts; and it seems to me to be the worst part of the system to give this species of premium on danger.

It may appear singular that I have so long delayed bringing this plan forward; and I should have done so long since, had I not expected something to be done to improve the mines, and ameliorate the condition of the poor suffering workmen: but I can no longer let any consideration of the unpleasant task of exposing and inflicting pain on individuals interfere with my more public duty, but openly come forward, at all risks, in the earnest hope of drawing some effectual attention to the subject.

APPENDIX (B.)

Appendix B.

Mr. Fourness' first letter on Fan Ventilation.

LETTERS FROM MR. FOURNESS, LEEDS, ON FAN VENTILATION.

Leeds, 5th August, 1839.

Sir,

Your kind letter of inquiry duly came to hand, and my being from home has prevented me from addressing you sooner. In answer, the limits of a letter prevent me giving you a full detail of my ideas on the subject, however I will endeavour in part to illustrate it :—

First,—A furnace is not calculated to answer the purpose (effectually) for which it is intended.

Secondly,—It is too weak an agent, and not to be depended upon; and if made sufficiently powerful, *it would be an impossibility for the workmen to ascend and descend the shaft, the intense heat near the bottom, in connection with the sulphur from the fire, would smother them, and eventually set fire to the sides of the upcast shafts.*

Thirdly,—If some other method or methods are not adopted, accidents of a serious or a minor nature must ever be taking place. As fire and water are two opposite elements, the furnace at the bottom, and the greater or less quantity of water behind the sheeting-boards of the upcast shaft, and each acting in its own capacity, are struggling to the utmost; but which is to be superior, however, in the shape of hot or cold bodies, the effect of the heat must give way to the colder bodies which surrounds it; indeed, its not any thing else but a perfect refrigeratory of the first order.

I find from experience the uniform temperature of the upcast shaft to be 62° Fahrenheit, whilst those of the working are at 60°; the upcast being at 62°, and the working at 60°, shows an increased temperature of 2°.[a] Now air or gases expand for every additional degree of temperature Fahrenheit, $\frac{1}{480}$ part, consequently 2° must be $\frac{2}{480}$ To find the quantity of air passing through the workings, the following simple rule will give it :—Upcast shaft or lifting power 2°, or $\frac{2}{480}$, find the area and contents in cubic feet contained in any given length, allowing air at 60° to weigh 1oz. 2grs. to the square foot: deduct from the whole weight of column or product $\frac{2}{480}$th which will be the difference in weight caused by the furnace. Then say, the area of the wind-path 21 feet, divide the $\frac{2}{480}$th by 21, which will immediately show the pressure on each square foot; and by looking into Smeaton's table on the velocity and perpendicular force of the wind, you will get the answer: I find it about 7·25 feet per second. This is something like one-half of what it should be; and if doubled, the same effect must be produced as I have noted at the commencement of this letter. It would require more than as much more fuel to be consumed; if I say four times the quantity, I should not be very far wrong, to course a current of air through the area of 15 feet at 14½ feet per second. The quantity certainly seems to be out of reason, but when we consider the upcast shaft so complete a condenser, and the great affinity hot bodies have to coldness, and the celerity in cooling being according to, or in a ratio with the increased temperature, we need not wonder at the quantity required. If the furnace is kept regular, the current passing through the pits will always be the same. I think I can show you, if kept regular, it will not answer the purpose. Suppose this morning the barometer stands as high as 30, and in the evening falls to 29, one pound on the square inch is taken off the blowers, fissures, &c., where the gas is generated, consequently $\frac{1}{30}$th more of carburetted hydrogen is permitted to come into the works, and thereby renders them dangerous to work in. If it could be so contrived to raise the temperature of the shaft $\frac{1}{30}$th more, perhaps all would be right, but this is impossible; also the support of the roof is considerably diminished, equal to 144lbs. on each square foot. Hence arises, in part, the cause of falls from the roof when the pits are most dangerous; and those falls, adding at the same time an additional body of destructive matter, make the thing then unavoidably complete, and wherever flame comes in contact with it, combustion immediately takes place. Hence arises the necessity of three furnaces for two downcast shafts at Russells' Wallsend, which is not a safe mine, the air having to be split, cannot be depended upon: one furnace might get the ascendancy over the other by the least neglect, and I need not tell you the result.

My plan is a rotatory fan, of rather novel construction: the inlets on each side are the same area as the fan; round about the extreme diameter is 61 apertures for the egress of air, equal to an area of 17 feet, which is delivered into the atmosphere. The fan is placed on the pit hill; a gone-by pit will do; has no pipes; requires a four-horse engine to work it; consumes 14 cwt. of best coal per 24 hours, and causes a current of air to travel through the workings at 7 to 21 feet per second, as necessity may require, how much fuel would the furnaces consume to cause a current equal to this?[b] I should say about 8 tons per day of 24 hours. *If $\frac{1}{30}$th of the atmosphere is taken off, this apparatus increases its velocity exactly $\frac{1}{30}$th more per minute, therefore in all cases the pit is the same.* If you would hear more from me, it must be by person, the limits of a letter are too small. I have not half explained myself.

I have not room to say more; only if you consider it necessary I will produce for you the signatures of approval of the most eminent, philosophical, and chemical gentlemen we have in this neighbourhood. I should be glad to hear from you as early as possible.

I remain, Sir,

Your most obedient and humble servant,

W. Fourness.

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[a] This is quite an error in Mr. Fourness: there is not unfrequently a difference of 50°, 60°, 70°, and 80° between the temperature of the upcast and the workings.

[b] The size is 5 feet diameter, by 2 feet 9 inches wide: travels from one to 300 revolutions per minute.

Leeds, 20th August, 1839.

Appendix B.

Mr. Fourness' second letter on Fan Ventilation.

Sir,

In your letter of the 13th inst., you stated you would be glad to receive any further communication from me on the subject of coal mine ventilation, I therefore hereby again take the liberty of addressing you. My last was principally on the causes of explosion: this, on the prevention of those fatal and dreadful occurrences which are highly calculated to desolate the domestic hearth, to carry the voice of mourning and visitations of bereavements into families, which never can be erased from the memory of the oldest inhabitant, and especially from the minds of those who are more immediately connected with the sufferers. Sir, you will readily allow that the cause of those accidents is the want of a better ventilation, or a larger quantity of atmospheric air passing through the works.

If a sufficient quantity of atmospheric air was introduced, not any individual would surely say an explosion would sooner take place in the mine, than it would, where not any explosive matter existed. I will allow that all systems have been adopted for the safety of the miner, or at least all which at the time seemed to be practicable. I have seen excellent methods adopted; as also I have heard of very absurd ones. A very eminent viewer, who has the management of an extensive colliery on the banks of the Tees, conceived he could improve the current of air passing through the workings, by an expensive and non-philosophical method which he indulged in, and set it in full work, but it was a failure. This eminent viewer's plan was to fix an iron rim or tubbing round the mouth of the upcast shaft, and by means of a fire caused it to be red-hot, the flues of the fire being behind the same: and he supposed the rarefaction would increase the velocity of the current, but it would not answer, and was immediately dispensed with. I do not say, if it had been properly placed, it would not have answered every purpose intended: that is, 40 or 50 yards down the shaft, this certainly would have been more expensive and not so convenient; the column of rarefied air caused by this red-hot rim or tubbing was immediately delivered into the atmosphere on the pit hill, therefore its exhausting power was driven to the winds. Another eminent gentleman, who figured high in a Newcastle paper, stated that the invention was an old one—had it not, a certain "eagle-eyed viewer" would have immediately recognized it. * * * * *

The method which has been adopted for upwards of 100 years, is as follows (alluding to the use of fans):—The fan is fixed on the brow of the pit, and from it pipes are carried to the place requiring ventilation: by forcing air down, of course a partial relief is experienced. Now, this plan, I consider, places the cart before the horse. For instance, supposing in sinking a single shaft, the sinkers are 170 yards from the top, this pipe must reach the place where they are at work; on driving the air down the pipe, there is a tremendous column of air to lift in the shaft, of such a weight as to prevent the machine from acting up to its power, also many escapes may be calculated on at the joints, &c.; all this arises from the resisting weight and power of the perpendicular column of air in the shaft. It would be much better to exhaust the air; supposing the machine to be at rest, the air in the pipe and the shaft are at par, all the lifting power required is the height of the delivering point above the level of the shaft, and a trifling allowance for friction. I will now endeavour to explain my apparatus, and, you must judge for yourself whether the plan is an old one or not. Mine consists of a rotatory fan, with inlets the size of the fan, let its diameter be what it may; at its extreme diameter, is a shield composed of iron to the amount of 61 pieces, each overlapping another all the way round. An opening is left between each, of 1 inch broad, and 2 feet 9 inches long, which is the breadth of the fan. The advantages held out are simply those:—1st. The air which the fan has to contend with is delivered as it receives it. 2nd. The inlet being the same size as the fan, saves an immense power, because the air has not to be wire-drawn as in other fans; and 3rdly. Its real power of exhaustion is nearly equal to four times the amount of any other fan in existence. A common fan has a great deal of compressed air to carry round to the delivering point, therefore the receiving point cannot be allowed to be larger than what is at present used, and making a most dreadful humming noise: on my plan there is not anything of the kind, because I have not any compressed air. My plan resembles the old-fashioned fan for cleaning corn, which is merely four pieces of sacking nailed on to wood; and when set in motion, throws its air off on every side. If one of those old-fashioned machines were turned the same number of revolutions per minute as those winnowing machines now in use, they would make four times the quantity of wind, though uncollected. You understand I don't want my air from my apparatus to be collected after delivery, but to mix with the atmosphere and get away to where the wind will take it to.

The following table will give the effect produced by different experiments: at the time they were tried there was 4½ miles of wind-road, and four downcast shafts of the following depths, namely, 76 yards, 73, 56, 44,; the air was exhausted up a staple pit, to which a cupola was fixed for ventilating the 73 yards' pit; this, of course, was cut off by means of a door, which was shut when the machine was working, or left open at pleasure: when left open, fire and smoke were delivered off the cupola fire; the experiments were made with the door shut:—

At 240 revolutions per minute, with close case, the perpendicular force was 3℔s. on the square foot.

At 240 revolutions per minute, without case, and the fan open to the atmosphere, the perpendicular force was 5℔. 12oz. on the square foot.

At 240 revolutions, with shield on, as described above, and ventilated in 61 openings, the perpendicular force was 6℔. 4oz. on the square foot.

This apparatus had narrow inlets, which, I find, is very detrimental to the power of the machine. I made a model of one of 5 feet diameter, on a scale of two inches to the foot, with inlets as large as the fan. I left passages for air to rise to those inlets, 5 feet by 2 feet: at 130 revolutions per minute, in any part of those passages, it would take a piece of paper from my fingers. I then reduced it to 14 inches by 18 inches: on turning the machine 130 revolutions per minute, I found the current of air not any stronger than it was on any part of the passage when entirely open; therefore, you will perceive under what disadvantages my experiments were made, a sum-

Appendix B.

Mr. Fourness' second letter on Fan Ventilation.

mary of which is described above. Suffice it to say, when two pits were on only, the water in the wind-road leading from an adjoining pit was thrown from the bottom and over the men passing through it, this has been always the case in that part of the pit: this was only half the air, the other half going round the workings of the other pit. I have been in one of those pits immediately after the men have come out for fire-damp; the apparatus has been set on, and I have soon found it perfectly "sweet." Another instance of its superiority is, a level is driven between two shafts at Osmondthorpe Colliery, and about 18 months before my experiments were made at this place, the carburetted hydrogen gas fired, and set the coal on fire in this level; every exertion was made to get the foul air away after it was opened into, but without effect, until my apparatus was applied, which cleared it in a few minutes, delivering heat, smoke, and other noxious vapour, which I cannot name; and although mixed with the air from the working of another pit, the heat, when delivered to the day, was sufficient to burn your hand. Let me induce you to give this invention a fair trial, feeling assured it must give universal satisfaction wherever it is applied. The cost will not exceed £320, which will soon be saved by economy in fuel, saving pit sides, ropes, &c. &c. The air from the mine is turned into the engine chimney (should any thing happen the machine) at a sufficient height above the flue from the boiler, that combustion cannot take plaee; this rarefied column of air, in connection with the steam, being turned into the flue for the purpose of increasing the temperature, a very good ventilation will be kept up. It is not liable very soon to be out of repair: were you to see the strength of the materials it is composed of, you would also say so. I have one complete, and another nearly so, trusting the Committee will give it their most serious consideration: the arrangements, &c., shall be fixed on the most equitable terms. The names of the individuals who understand the merits of my mode of ventilation, I have not yet got, as I have not had an opportunity of seeing all of them, but am making arrangements to send you their testimonials shortly.

I remain, Sir,
Your most obedient and humble servant,
W. Fourness.

Appendix C.

Mr. Taylor's minutes. I. Tension of Fire-Damp.

APPENDIX (C.)

MINUTES ON SOME CIRCUMSTANCES CONNECTED WITH EXPLOSIONS OF FIRE-DAMP IN COAL MINES. MARCH, 1842.

BY T. J. TAYLOR, ESQ., OF EARSDON.

I. TENSION OF THE FIRE-DAMP OF MINES.

We are accustomed to refer the issue of gas in mines to the state of the barometer, and no doubt this has considerable influence; but I am persuaded that an increase of issue, due simply to the fall of the barometer, would seldom be sufficient to mix the air current to the firing point, provided the ventilation were of the average degree of efficiency. I mean such as we actually have it, and as it has been proved to exist in mines where heavy explosions have, nevertheless, taken place. I have long leant to the belief, that the majority of *great* explosions is due to *sudden issues of gas pent up in a high state of tension*, and against which, therefore, no system of ventilation (or dilution) now in proctice can adequately guard. That there are exceptions to this cause of explosion I am aware, because it is clear, that if no air current, or an extremely feeble one, is moving through a mine, then the slow issue of even a small quantity of gas is sufficient to foul it; but the exceptions to which I allude were much more numerous formerly than they are at present under improved systems of ventilation. I will mention a few facts in illustration of the sudden and violent discharge of fire-damp.

At Haswell Colliery, two years ago, an eruption of this kind took place at the face *a* (Fig. 1, Appendix) of a coal drift, the sectional area of which is 37 square feet; the quantity of air circulating in the drifts (as tried a few days previously) was 9760 cubic feet per minute, whence the velocity of the current was 4·39 feet per second, a velocity much greater than that of the average of the air currents of a coal mine. The point of issue was at *a*, where the hewer was at work as usual, when he heard a noise, like that of a water-fall. Fortunately these drifts were being worked with the Safety Lamp, and therefore no explosion ensued upon this violent discharge of gas. An officer was in the other drift, *b*, at the time, and on examining the return air channel found it foul as far as x, 310 yards back from the face. In half an hour the air current had swept away all traces of this discharge, and things went on as usual.

It is probable that the drift was fouled beyond *x*: but without any allowance for this, there would be not less a quantity than about 4,000 cubic feet of gas discharged at this eruption (being about $\frac{1}{10}$th of the space known to be foul), and yet no traces of it were to be found after the lapse of half an hour.

This account helps to explain the obscurity which may, and so often does, hang over the immediate causes of pit explosions. Had the fire-damp been ignited, evidence would have been given

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I. Tension of Fire-Damp.

(and correctly) that the places were free from it in the morning when the overman made his inspection: it would have been found, on examination, after the removal of the after-damp, that no fire-damp continued to be given out; while, with regard to the intermediate stage, being the only one capable of furnishing a true explanation, no testimony would have been obtained. It is more than probable that many explosions are to be accounted for in a similar way, and it will be observed, that on this basis, some apparent anomalies in the evidence of witnesses on an inquest are explained away, especially those which relate to the pre-existing efficiency of the ventilation and general safety of the mine.

I shall now relate another example of the sudden discharge of fire-damp in mines. Though not so easily traceable as the former one, it is interesting, as having occurred in the Bigge Pit Bensham, Willington Colliery, where an explosion, attended by the loss of 32 lives, took place in April last; and, if I am not mistaken, as furnishing a key to the direct cause of that explosion.

On the 30th September last, the master wasteman, John Harrison, was at work in the return air course, where the current was travelling towards the upcast shaft, *after circulating through the whole of the workings.* There were no people in the pit at the time except himself, a boy who was with him, and some masons and their assistants, who were employed in building a ventilating furnace, and who were in another air current, distinct from the one which had travelled round the workings. Harrison had two lamps with him, a Davy lamp and a Stephenson's lamp, both of which were hung upon props near him. After working a short time, he observed that Stephenson's lamp went out, and this having drawn his attention, he then saw that the Davy lamp was filled with flame, shewing that he was in the midst of an atmosphere mixed to the firing point, and that it had *suddenly become so*; for there was no such thing when he came there. Harrison quitted the place, and after making some arrangements for the safety of the other persons in the mine, he returned in about twenty minutes, and found that the air current was then free from admixture with fire-damp. He also forthwith went round the whole of the workings, and found no trace of fire-damp in any part of them. At the time this discharge of gas took place, no change had been made in the ventilating arrangements: everything being in *statu quo.*

I examined this mine soon after the explosion of the 19th April last, and though the ventilation was then imperfect, (not having been adequately restored after the wreck of the explosion,) I found only one place in the mine which fired in the lamp, and this was at the highest nook of a working place. Reasoning *a fortiori*, there should have been still less, if less could well be, when the ventilation was perfect: and being struck with the extremely small quantity of fire-damp found in this mine under circumstances much more favourable to its existence than those which existed immediately previous to the explosion,[c] I was at the time of opinion, that the explosion had been owing to a sudden discharge of fire-damp. I need not say, that my views had been confirmed by the circumstance observed by Harrison. Had the discharge of the 30th September been ignited, the explosion would, in all probability, have been much more violent than that of the 19th April; because, in the latter, the explosion did not extend along the return, which it would have done on the 30th of September.

Attempts were made to trace this discharge of gas to its origin, but they were unsuccessful. Neither could the Haswell discharge be traced to crack or *cavity*, though it was seen coming off: there was some disintegrated coal where the issue took place, and nothing more. There is this distinction between the two cases, that the Haswell issue occurred when the workmen were in the act of removing the coal: while the Willington one took place at a time when coal work was suspended, and consequently when no new surface was being exposed.

It is quite clear, that in both the cases described, the discharge of gas was quite unconnected with the state of the barometer. It is also obvious, that in one of them (the Haswell case) the tension of the issuing gas was very great; and though we cannot positively declare the same of the other, since it was not observed at the point of issue, yet it is evident that the quantity discharged was also in this case very great in a short time, and this is sufficient to establish a parity of reasoning.

These examples (I might mention others) will serve to show that of the two direct causes of pit explosions—one to the gradual fouling of the air current by a slow discharge of gas—the other to sudden and violent issues—the first is, or may be brought under our controul, by dilution with air; while the second cannot be so managed, but must be averted either by preventing the contact of unprotected lights, or by some other means yet unknown.

There has not been any gage of the tension of fire-damp issuing under the circumstances described; but we know something of the tension it is capable of assuming where it forces its way through water in drowned up shafts; for in doing so, it must overcome the pressure of the vertical column of water opposed to its issue; and just before eruption takes place, there is an exact balance between the forces, the column of water on one side, and the confined gas on the other. I have had an opportunity of examining very closely the progress of one of these "water-blasts," being that from the Percy Main Bensham in March, 1840, which discharged, according to my calculation, 12,686,000 cubic feet of gas in 68 hours: the gas being considered as expanded from its confined proportions to the volume it would assume at the ordinary pressure of the atmosphere. From the details of this water-blast, I select such as are calculated to shew the tension at which it issued. The principle of a water-blast is shewn in the diagram (Fig. ii. Appendix): *a c* is the shaft, *c d* a profile view of the workings, rising gradually as they recede from the shaft. The confined air was drawn off from the workings during the process of filling with water by pipes

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[c] Amonst those circumstances, I must not omit one; the barometer was much *lower* on the day of my visit than on that of the explosion.

Appendix C.

Mr. Taylor's minutes. I. Tension of Fire-Damp.

along *d* c, which were carried up the shaft, so that both ends of the pipes were free, while the intermediate portion was immersed: the pipes were not carried quite so far as *d*, and therefore a portion of common air remained in the workings at the highest point of them. The water rose to *a*, and stood there for some months, flowing off at this level into an upper seam.

When the water was taken out it lowered rapidly to *b*, but beyond *b* more slowly; at *b* the water may be conceived to have stood at the level *e* in the workings, *d e* being filled with compressed gas: still continuing to take out the water, it fell very slowly to *f*, for at this time the forces were approaching an equilibrium, and therefore as fast as the water was lifted out of *b f*, another portion of water was forced into it by the pressure of the confined gas; this continued until the water stood at *c* in the workings, and at *f* in the shaft, when the eruption of confined gas took place. At this time there were 19 fathoms of effective water pressure in the shaft, being about $3\frac{1}{6}$ atmospheres, and adding the natural atmosphere, we have the tension of the confined gas equal to $4\frac{1}{6}$ *atmospheres.*

Now, we have here a tension adequate to cause the sudden and violent discharges of gas of which I have given examples: a tension, whose excess over that of the atmosphere, is just about equal to that of the high pressure steam with which locomotive engines are worked. And, so far as the case under consideration carries us, this would appear to be a *maximum* tension; for, as has been observed, there was a small quantity of compressed common air left in the mine, and this, under the full pressure of the water, would have a tension of 5 atmospheres in one part of the mine, and $7\frac{1}{2}$ atmospheres in another. It appears then that the gas was not able to maintain this original degree of tension, since it fell from $7\frac{1}{2}$ and 5 to $4\frac{1}{6}$; and it is remarkable, that after reaching the latter degree, it continued *steadily at it*, being never lower than $4\frac{1}{6}$ atmospheres: this is the proper measure of the tension it is capable of assuming.

The cases I have mentioned suggest many points of inquiry into circumstances of which very little is at present known: such are the following:—

1. Looking to the fact, that fire-damp is either existent in, or capable of assuming, a high degree of tension, why do we not meet with it invariably in this state, instead of finding it most commonly otherwise, insomuch that the discharge is governed by slight differences of barometric level, bearing a very small ratio to its inherent force?

2. Must we not assume from this circumstance that the great body of fire-damp in mines does not exist, *in situ* in the aeriform state, but only passes into that state; for, if it were in the aeriform state, it should, by the laws of fluids, immediately communicate all the pressure of which it is capable, whereas the reverse is the fact, except in the cases where sudden gusts of gas are discharged. These latter, from their rarity,[d] must be regarded as exceptions, and how have we to explain them as such?

3. If the great body of gas is not in the aeriform state, but only some extravasated portions of it, in *what state* does the gas exist? In the case of the water-blast, we have seen that it requires *time* to develope the full elasticity of the gas, and this seems to indicate some cause of resistance to the expansive force, as if the gas were imbibed by, or entangled with, the solid substances of the mine, in such a way as to prevent its escape except with slowness. I am not sure that a solid or liquid form of the gas, arising from great pressure, is the state that will explain all the phenomena; for, in such case, we should expect it to dash out, as it were, into gas, the instant the pressure is removed: yet this is not the case, except in rare instances, if then; for we should expect a still higher tension to be exhibited if a transition were made from the solid or liquid state.

4. It would appear from the Percy Main experiment (for such it may be called), that a pressure of between 4 and 5 atmospheres *prevents the gas from developing itself in the aeriform state;* for we find that it remained constant at this rate of tension. It is not to be supposed that the feeders were exhausted; on the contrary, more gas must have continued to be given off in order to maintain it at this tension as the space expanded; and, besides, gas in abundance has ever since continued to be given off, and is now, after the lapse of nearly two years. It issues, at present, under the ordinary atmospheric pressure.

What, then, is the nature of the influence that a pressure of from 4 to 5 atmospheres exercises upon fire-damp, so as to hinder its developement in the gaseous state?

II. LAW OF THE DIFFUSION OF GASES, AS ILLUSTRATED IN MINES.

Mr. Taylor's minutes. II. Law of the Duffusion of Gases.

So far as my own observation goes, no *practical* data of value can be deduced from the law of the diffusion of gases, when applied to what occurs in mines. It is very usual to find the upper stratum of air in a gallery explosive, while the lower one is not so; and I have had an opportunity of examining the confined air of a district of some acres in extent, where the workings had an inclination in the manner shewn by the profile *A B*.—(Fig. iii. Appendix.)

At *B*, the highest point, I found a very explosive mixture, and no trace of carbonic acid gas could be detected by lime water; at *A*, the lowest point, the mixture was not explosive, and there was a good deal of carbonic acid. It may be said that the mixture at *A* might be explosive, but that this property was destroyed by admixture with carbonic acid. Still there remains the circumstance that carbonic acid was not found at *B*. This district had been barred off by tight stone walls from the rest of the mine for six weeks when I examined the issuing air.

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[d] I speak relatively as regards the existence of fire-damp in different states, and not as regards the cause of explosion. On the contrary, I believe that the greatest number of destructive explosions is due to the issue of sudden discharges of pent up gas.

Appendix C.

Mr. Taylor's minutes. II. Law of the Diffusion of Gases.

It appears then, that we cannot surely calculate upon the results of the diffusion of gases in mines, but that there are practical qualifications of such moment as to render the law of little or no use. In drawing attention to this circumstance, and seeking an explanation, I am unwilling to offer any suggestions of my own.

III. INTERMITTENT NATURE OF PIT EXPLOSIONS.

Mr. Taylor's minutes. III. Intermittent Nature of Pit Explosions.

It has been observed that great explosions in mines are not always simultaneous, but generally (perhaps always) intermittent—say, two or three in number, succeeding each other at intervals of some seconds, and with a period of repose between them One is disposed to ascribe this result to a communication with different reservoirs, which are fired in succession; yet I do not think this is the sole cause. Were it so, there would be a greater number of these intermittent blasts, commensurate with the numerous galleries into which the fiery district is divided, whereas we do not find more than two or three occurring. What is the cause of the cessation, and then of the renewal of the explosion?

IV. NATURE OF AFTER-DAMP.

Mr. Taylor's minutes. IV. Nature of After-Damp.

It would seem that nitrogen is a main agent of destruction in after-damp, since the deadly atmosphere of a mine, after explosion, must contain a much greater quantity of this gas than of carbonic acid. In attempting to recover persons from the effects of after-damp what influence ought this circumstance to exercise upon the mode of treatment? What is the cause of the peculiar odour of after-damp, an odour not unpleasant, and resembling a faint smell of ripe apples. The air forced from the lungs of a man after death had this odour, though he lived many days after being burnt.

APPENDIX (D.)

Appendix D.

Analysis of Iron Pyrites.

ANOTHER ANALYSIS OF IRON PYRITES FOUND IN THE TYNE AND WEAR COAL MINES.

The following analysis of the iron pyrites, found so abundantly in the coal mines of the Tyne and Wear districts, was received too late for its place in the text. It is from a gentleman, an excellent chemist, the most extensively engaged in the kingdom in alkali manufactures. It differs in a small degree, varying from 3 to 8 per cent. of sulphur, from that already given, which of course does not effect the result as stated in the production of the sulphuretted hydrogen gas in coal mines. This analysis is, however, appended, as the Committee are anxious to secure the most correct data on every point, even indirectly, bearing on the subject of their inquiry.

He states:—

"I give you the analysis of a piece of coal-pyrites, a part of which I enclose you.

100 grains contain—

Iron,	51·00
Sulphur,	42·
Insoluble coal, &c.,	7·
	100·00

"We have received pyrites under 30 per cent., but the note where I state 30 to 45 per cent., will be found correctly given as to the general average of pyrites used in the manufacture of sulphuric acid."—15th September, 1842.

APPENDIX (E.)

Appendix E.

List of Explosions and Accidents.

LIST OF EXPLOSIONS AND ACCIDENTS IN COAL MINES,

IN THE NORTHUMBERLAND AND DURHAM DISTRICT, FROM 1658 TO 1842.

In this list are 10 accidents, containing 23 deaths, not included in Sykes' list, and since he published in 1835, 21 accidents, with 192 deaths. This, though the most correct and full list of accidents in the Coal Mines that has been published, yet there is good reason to believe, contains, not nearly the whole that have occurred in the period it embraces. For the future, the books of the Registrar-General will supply a perfect account of accidents and their causes; but it is deemed proper to preserve this account, obtained by individual research, imperfect as it may be, until the period of the legalized registration. The Committee have resumed their list and remarks, from the period of 1799, to August, 1841, of which they gave a copy to Sub-Commissioner Leifchild, for the Report of the Children's Employment Commission. During 20 years previous to the adoption of the safety lamp, when steel mills, &c., were in use, 679 lives were lost; since 1820, in the succeeding 20 years, when it may be said to have been in general use, 744 lives were lost, leaving a balance against the safety lamp of 65 lives, but which, perhaps, may be partly accounted for by increased extent of works and greater number of mines.

DATE.	COLLIERIES.	LIVES LOST.	CAUSES.	REMARKS.
1658. May, ...	Gallow Flat, near Elswick,....	Number unknown	Inundated from an old waste,..	Two bodies, nearly 37 years after the inundation, were recovered almost entire, scarcely affected by the water in all that time.
About 1710,....	Bensham, ...	70 to 80	Exploded.	
1743. Jan. 18, ..	North Biddick,............	17	Ditto.	
1756. August 11,	Chaytor's Haugh, ...	4	Ditto.	
1757. June 10,..	Ravensworth, ...	16	Ditto.	
1760. June 15,..	Long Benton, ...	1	Ditto.	
1761. Dec. 1, ..	Hartley,....................	5	Ditto.	
1765. April 2, ..	Walker,....................	8	Ditto.	
1766. March 18,	Ditto, ...	10	Ditto.	
1766. April 16,..	South Biddick,.............	Several	Ditto.	
1766. August 22,	Lambton, ...	6	Ditto.	
1767. March 27,	Fatfield,....................	39	Ditto.	
1773. Dec. 6, ..	A Colliery near the Wear, ...	Several	Ditto.	
1776. October 7,	Ovington's Pit, East Rainton,..	2	Ditto.	
1778. Dec. 8, ..	Dolly Pit, Chaytor's Haugh,..	24	Ditto.	
1780. August 21,	Birtley North Side, ...	3	Ditto.	
1782. May 17,..	The Fauld Pit, Gateshead,....	4	Ditto.	
1782. Oct. 11,..	Wallsend, ...	1	Ditto.	
1783. May, ...	Washington,...............	2	Ditto.	
These occurred between the years 1783—94	Washington,...............	2	Ditto.	
	Ditto, ...	2	Ditto.	
	Lambton's A Pit Bourn Moor,	1	Ditto.	
	Ditto B Pit Ditto, ...	Several	Ditto.	
	Ditto Lady Ann Pit, Morton,..	2	Ditto.	
1784. Nov. 6, ..	Wallsend, ...	3	Ditto.	
1784. Dec. 12,..	Ditto,.....................	2	Ditto.	
1785. June 9, ..	Ditto,.....................	1	Ditto,........	At the Steel Mill. Up to this period, the Steel Mill was considered a safe instrument, when John Selkirk, who survived this explosion, and was "playing" it at the time, proved it to have occurred by a spark from his mill.
1785. Dec. 4, ..	Ditto,.....................	2	Ditto.	
1786. April 9, ..	Ditto,.....................	6	Ditto.	
1790. Oct. 4, ..	Ditto,.....................	7	Ditto.	
1793. Dec. 27,..	Hope Pit, Sheriff Hill,........	14	Ditto.	
1794. June 9, ..	Rickleton Pit, near Picktree, ..	30	Ditto.	
1794. June 11,..	Harraton, ...	28	Ditto.	
1794. November,	Glebe Pit, Oxclose,..........	2	Ditto.	
1794. Dec. 21, ..	Hope Pit, Sheriff Hill,........	Several	Ditto.	
1795. April 24,..	Paradise, or West Pit, Benwell,	11	Ditto.	
1796. Feb. 12,..	New Washington, ...	7	Ditto.	
1796. April,....	B Pit, Washington,..........	2	Ditto.	
1796. Sept 8, ..	Slatyford, ...	6	Inundated.	
1798. Feb. 27,..	B Pit, Washington,..........	7	Exploded.	
1798. May 22,..	Glebe Pit, Oxclose, ...	4	Ditto.	
1799.	Jane Pit, Newbottle, ...	1	Ditto.	
1799. August 13.	A Pit, Oxclose,..............	1	Ditto.	
1799. Oct. 11,..	Lumley,....................	39	Ditto.	
1803.	Morton Pit, Lambton,........	2	Ditto.	
1803. Sept. 25,..	Wallsend, ...	13	Ditto.	
1805. April,....	A Pit, Oxclose,..............	2	Ditto.	
1805. Oct. 21, ..	Hebburn, ...	35	Ditto.	
1805. Nov. 29,..	Oxclose,...................	38	Ditto.	
1806. March 28,	Killingworth, ...	10	Ditto.	
1808.	New Pit, Shiney Row, ...	2	Ditto.	
1808. August 31,	Hall Pit, Fatfield,............	3	Ditto.	
1808. Nov. 29,..	Harraton, ...	4	Ditto.	
1808. Nov. 30,..	Hall Pit, Fatfield,............	3	Ditto.	
1808.	Collin's Pit, Rainton, ...	2	Ditto.	
1808.	B Pit, Oxclose,..............	1	Ditto.	
1808.	Houghton Gate Pit, Lambton,	2	Ditto.	
1809. Sept. 14,..	Killingworth, ...	12	Ditto.	
1812. May 25,..	Felling, ...	92	Ditto.	
1812. Oct. 10,..	Harrington Mill Pit, Pensher,	24	Ditto.	

Appendix E.

List of Explosions and Accidents.

Date.	Collieries.	Lives Lost.	Causes.	Remarks.
1813. July 17,	Collingwood Main,	8	Exploded.	
1813. Sept. 28,	Hall Pit, Fatfield,	32	Ditto.	
1813. Dec. 24,	Felling,	22	Ditto.	
1814. April 5,	Howden Pit, Percy Main,	4	Ditto.	
1814. August 12,	Hebburn,	11	Ditto.	
1814. Sept. 9,	Leafield,	4	Ditto.	
1814. Dec. 24,	Shilbottle,	4	Choke-damp.	
1814. Dec. 31,	Mountmoor,	4	Chain broke.	
1815. March 8,	Pensher,	3	Choke-damp.	
1815. May 3,	Heaton Main,	75	Inundated,	Penetrated old workings of another colliery, showing the necessity of a regular registered plan, as in France and Belgium, of the workings of every colliery.
1815. June 2,	Success Pit, Newbottle,	57	Exploded.	
1815. June 27,	Sheriff Hill,	11	Ditto.	
1815. July 31,	Newbottle,	18	Bursting of the boiler of a high-pressure locomotive engine.	
1815. Dec. 11,	Sheriff Hill,	5	Shaft brattice firing.	
1815. Dec. 18,	Townley,	1	Exploded.	
1817. June 30,	Row Pit, Harraton,	38	Ditto.	
1817. July 2,	Nova Scotia, Harraton,	8	After-damp.	
1817. July 21,	Sheriff Hill,	1	Exploded.	
1817. Sept. 25,	Jarrow,	6	Ditto.	
1817. Nov. 3,	Ouston,	1	Ditto.	
1817. Dec. 18,	Plain Pit, Rainton,	27	Ditto.	
1818. August 5,	Wallsend,	4	Ditto.	
1819. July 19,	Sheriff Hill,	35	Ditto.	
1819. Oct. 9,	George Pit, Lambton,	13	Ditto.	
1819. Dec. 18,	East Rainton,	1	Ditto.	
1820. April 28,	Jarrow,	2	Ditto.	
1820. Oct. 1,	Backworth,	1	After-damp.	
1821. June,	Elswick,	4	Crushed by fall.	
1821. July 9,	Rainton North Pit,	1	Exploded.	
1821.	Coxlodge,	1	Ditto.	
1821. Oct. 19,	Nesham's Newbottle,	6	Ditto.	
1821. Oct. 23,	Wallsend (Russells'),	52	Ditto.	
1821. Oct. —,	Felling,	6	Ditto.	
1822. May 6,	Ditto,	1	Ditto.	
1823. Oct. 21,	Ouston,	4	Ditto.	
1823. June 19,	Walker,	7	Falling in of earth.	
1823. Nov. 3,	Plain Pit, Rainton,	59	Exploded.	
1824. Nov. 19,	Dolly Pit, Newbottle,	11	Ditto.	
1824. Oct. 25,	George Pit, Lumley,	14	Ditto.	
1825. July 3,	Judeth Pit, Fatfield,	11	Ditto.	
1825. Oct. 5,	Hebburn,	4	Ditto.	
1826. Jan. 17,	Jarrow,	34	Ditto,	Said to be produced by a boy, called Norman, 8 years of age, who left a trap-door open.
1826. May 30,	Townley,	38	Ditto.	
1826. Sept. 5,	Heworth,	5	Ditto.	
1826. Oct. 27,	Benwell,	2	Ditto.	
1827. July 20,	Charles Pit, Lumley,	1	Ditto.	
1827. Sept. 5,	Fawdon,	2	Ditto.	
1828. March 15,	Jarrow,	8	Ditto.	
1828. Sept. 1,	New Pit, Houghton-le-Spring,	7	Ditto.	
1828. Nov. 20,	I Pit, Washington,	14	Ditto.	
1828. Dec. 1,	Townley,	1	Inundated.	
1829. May 13,	Killingworth West Moor,	1	Exploded.	
1829. June 26,	Dorothea Pit, Newbottle,	1	Ditto.	
1829. Dec. 3,	Willington,	4	Ditto.	
1830. August 3,	Jarrow,	42	Ditto.	
1830. Nov. 27,	Hebburn,	2	Suffocation.	
1831. July 9,	King Pit, Wreckington,	3	Exploded.	
1831. Sept. 20,	Willington,	7	Ditto.	
2831. Dec. 6,	Middle Rainton,	1	Fall down the shaft.	
1832. March 7,	Beamish,	2	Inundated.	
1832. June 15,	Newbottle,	12	Boiler exploded.	
1832.	Monkwearmouth,	1	Fall of stone.	
1832. Oct.	Wallsend,	1	Exploded.	
1832. Nov. 10,	New Pit, Gosforth,	2	Falling down the shaft.	
1832. Nov. 13,	Heaton,	1	Exploded.	
1832.	Sheriff Hill,	2	Fall of stone from roof.	
1832. Dec.	Monkwearmouth,	1	Ditto.	
1833. May 9,	Springwell,	47	Exploded,	Davy lamps employed.
1833. May 24,	Great Lumley,	2	Ditto.	
1833. August 2,	Fatfield,	1	Fall of stone.	
1833. Nov. 8,	Blackfell,	3	Exploded.	
1833. Nov. 26,	Wideopen,	1	Boiler bursting.	
1834. Feb. 25,	Fanny Pit, Gosforth,	4	Corf unhooking.	
1834. March 28,	Buddle Pit, Pittington,	2	Corf blown down the shaft.	
1834. Sept. 17,	Elemore Pit, Hetton,	1	Boiler bursting.	
1834. Oct. 4,	Springwell,	2	Timber falling down the shaft.	
1834. Nov. 24,	Hartley,	4	Breaking of the shaft rope.	
1834. Nov. 24,	St. Lawrence,	3	Exploded.	
1835. Feb. 3,	Downs Pit, Hetton,	22	Ditto.	
1835. May 1,	Whitley,	6	Corf improperly hooked.	
1835. June 18,	Wallsend,	102	Exploded,	Davy lamps employed. 9 boys, under 12 years of age, destroyed in this explosion.
1835. June 30,	Backworth,	2	Fall of stone.	
1835. Nov. 19,	Burdon Main,	11	Exploded.	
1836. Jan. 27,	High Heworth,	4	Ditto.	
1836. Feb. 12,	Mushroom,	1	Fall down the pit.	
1836. July 19,	B Pit, Hebburn,	3	Exploded.	
1836. Sept. 29,	Lumley Pit,	1	Fall of stone.	
1836. Nov.	Jarrow,	2	Exploded.	
1837. March 24,	Norwood,	2	Chain broke.	
1837. April,	Monkwearmouth,	3	Ditto.	
1837. Dec. 6,	Springwell,	30	Exploded.	
1838. Jan. 24,	Stewart Pit,	2	Fall of stone.	
1838. Dec. 19,	Wallsend,	11	Exploded.	

Appendix E.

List of Explosions and Accidents.

Date.	Collieries.	Lives Lost.	Causes.	Remarks.
1839. June 28,..	St. Hilda,	51	Exploded,	6 boys, under 12 years, lost their lives in this explosion.
1840. Oct. 23, ..	Farnacres,	5	Drowned from old workings, ..	This inundation shows the necessity of registered plans.
1840. Dec. 19, ..	Shincliffe,	4	Exploded.	
1841. April 13,..	Whitley,	1	Ditto.	
1841. April 19,..	Bigge Pit, Willington,	32	Ditto,	Produced by a boy named Richard Cooper, 9 years of age, who had left his door to play with two other boys.—4 boys, under 9 years, killed at this explosion.
1841. August 5,..	Thornley Pit,	9	Ditto,	Caused by a trapper, Robert Gardener, under 9 years of age, who had neglected his trap-door.
1841. August 9,..	Cramlington,	1	Ditto.	
1841. August 17,	Haswell,	2	Ditto.	
1841. August 28,	Radcliffe Pit	1	Fall down pit.	
1841. Oct. 29, ..	Cramlington,	3	Stone fall.	

APPENDIX (F.)

Appendix F.

Accidents in the Coal Mines of Belgium.

ACCIDENTS IN THE COAL MINES OF BELGIUM,

FROM THE REPORT OF THE MINISTER OF PUBLIC WORKS FOR 1841.

From 1821 to 1840 inclusive, *the number of accidents* in the Belgick mines, including the provinces of Heinaut, Liege, and Namur, with Luxemburg, were 1,456; *producing deaths*, 2,148; of which 438 were by explosions of carburetted hydrogen gas, in addition to 380 severely wounded by the same cause. The number of men employed *on an average* in those mines during the above period were about 28,000. They now amount to nearly 38,000.

For the relief of the families and sufferers from such accidents, there are *Provident Institutions* which are supported :—

1st.—½ per cent., or less than 5 farthings in the £ of the wages of the workmen.

2nd.—The proprietors make up an amount equal to that subscribed by the men.

3rd.—Grants from the Government;[f] and

4th.—Donations from private individuals.

[f] Last year, 1841, the Legislature humanely voted 42,000 frans, or £1760, for this purpose.

Appendix G.

Memoir of M. Jars.

APPENDIX (G.)

The following able Memoir of M. Jars, on the Ventilation of Mines, has been deemed of sufficient importance to be translated and appended to this Report; and though containing errors discovered by the more advanced state of science and a better practical acquaintance with the subject of mines, yet it possesses great merit in its lucid exposition of many correct principles of ventilation, and, to this day, is frequently consulted by such of the well-informed viewers of Britain as are in possession of so scarce a work. A practical Report, such as the South Shields Committee is engaged in, would scarcely be complete without an Essay so valuable as M. Jars' being rendered, as far as possible, accessible to every officer of mines, treating, as it does, on one of the most important branches of their subject.

OBSERVATIONS ON THE CIRCULATION OF AIR IN MINES: THE MEANS WHICH IT IS NECESSARY TO EMPLOY FOR MAINTAINING IT.[g]

(YEAR 1764.)

BY M. JARS: MEMBER OF THE ROYAL ACADEMY OF SCIENCES OF PARIS; THE LONDON SOCIETY FOR THE ENCOURAGEMENT OF ARTS; AND ASSOCIATE OF THE ACADEMY OF SCIENCE, BELLES LETTRES, AND ARTS, OF LYONS.

TRANSLATED BY MR. JAMES MATHER, ONE OF THE SECRETARIES OF THE SOUTH SHIELDS COMMITTEE FOR THE INVESTIGATION OF THE CAUSES OF ACCIDENTS IN MINES.

The perplexity in which I have seen many Owners and Directors of Mines, both in France and Germany, to introduce air into the works which they managed, the useless works which they undertook to obtain this object, have induced a strong desire in me to know how the circulation of air was effected within the subterraneous passages, for the purpose of arriving at a sure method to introduce it there, thus avoiding those fruitless labours which in mines are always very expensive, and expelling the bad air, which greatly exhausts the miners, and somewhat shortens their lives.

Full of my object, I have spoken about it with whomever I knew well-informed in Geometry and subterraneous Physics; I have had many conversations on the subject with the *savans* of Freyberg, in Saxony; but, however instructive those conversations were, they always left me something to desire; therefore it is that I have continued to observe, and have sought at the same time the reason why air took one route in preference to another. I believe it to be attained.

This memoir might be susceptible of a very great extension, by the application which one could be able to make from the inferences that I have drawn from all my remarks, to prevent apartments from smoking, and to renew the air in hospitals and other places, &c., but my engagements, and the journey[h] which I am on the point of taking, prevent me doing anything more just now, than making these observations. I believe it a duty to the Academy, to make known the principal that I have made up to this time, and the advantages derivable from them.

It will be sufficient for every intelligent director and viewer of mines to understand the following observations, and the applications that I make of them, to serve to guide him in every case.

I have observed in winter, on visiting mines, with pits of 10, 12, to 20 fathoms (toises[i]) perpendicular depth, in which all the water that filtered through the rock and timber work, froze and became ice in all their height.

I have likewise observed that the thermometer of M. de Rèaumur placed in a mine at 45 paces from the mouth[j] of one of its galleries,[k] continued at zero (32° Fahr.): in the interval of that distance I have found ice, but in advancing into the mine, the fluid of the thermometer rose gradually to 11° and 12° Rèaumur (about 57° and 59° Fahr.)—that is to say, one or two degrees Rèaumur above the temperature of the vaults of the observatory, which is the same within the mines. I have attributed the two degrees above the temperature (nearly 5° Fahr.) to the air being heated by the workmen, and the flame of their lamps.

There are, again, in certain mines, some accidents which often occasion a very strong heat, as in works where are found a sort of pyrites, which, decomposing by the action of air, heats them up to such a point, that the workmen are obliged to labour without their shirts, and are only able to bear it a very short time.

The same mines where I have observed pits and galleries in which ice is found, had other openings where one felt on entering a heated air. I saw pass out by these same openings the smoke of gunpowder, which had been produced in one or more explosions in the mine, whence I have concluded that the air entered by the works where I have seen the ice, and passed out by those where was inspired a heated air.

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[g] This memoir was read to the Academy of Sciences in the year 1768, and printed in the volume of its memoirs for the same year.—Page 218 and 220.

[h] M. Jars was preparing to visit England, which he did in 1765.

[i] The toise is 6 feet 6 inches.

[j] They name mouth of a gallery or of a pit, its exterior opening.

[k] They name gallery, the horizontal subterranean excavations, which end in other excavations that are made to extract the mineral of a seam, which, whenever the mine is considerable, have commonly many exterior openings, which are perpendicular, horizontal, or oblique.

Appendix G.

Memoir of M. Jars.

I have remarked, at the same time, that all the works by which the air entered into the mine were inferior or lower than those by which it went out, which persuaded me that they would have so much more air where the works of the superior or upper communication were more elevated above the horizontal, or the level of those placed at the foot of the mountain.

These observations explained to me why they constructed stalks or funnels of chimneys upon certain pits of coal mines which were sunk in a flat country.

I had often inquired of them the reason, and they always replied that it was to introduce air into the mine; but I was ignorant why the air entered by the inferior or lower works rather than the higher.

Not content with having made during the winter the observations that I have related, I wished to examine if the circulation of the air was the same in all seasons; I was not able to establish anything during the spring of which we shall afterwards see the reason.

As my first observations had been made when it froze, I chose some hot days of summer to go through the different passages of the mine of Chessy, near Lyons. I have also made the same remarks in other mines.

I entered at first into the mine by the same inferior, or lower gallery, in which the thermometer had been in winter at zero (32° Fahr.), as far as 45 paces from the mouth; I felt the cold on entering; I placed my thermometer, of which the fluid was at 20 degrees above zero (77° Fahr.), at one fathom (toise) interiorily from the mouth of the said gallery; after having left it there for half an hour, the fluid descended to 11 degrees (57° Fahr.); I felt the same coolness in all the mine; I directed my course to the side of a work ascending upwards (montant[1]) by which they go out of the mine; it was then the highest opening. I remarked with surprise that in proportion as I approached the mouth the air grew warmer. I placed my thermometer at four fathoms (toises) within the said mouth, it rose to 18 degrees (73° Fahr.).

These observations, oftimes repeated in different mines, have proved to me that the air, which in winter enters into the mines by the inferior works, to go out by the superior, takes the contrary route during summer.

It was not sufficient for me to know clearly the mode in which the air circulates in the mines; I wished yet to know what was the reason, and that which caused the air for a season to take one route preferable to another.

Let us see the reasoning which I have drawn from it, and in what way I prove it.

I suppose *A B* (figure 1) a gallery, at the extremity of which there is a pit *C B* of 10 fathoms (toises) deep; its mouth *C* is then 10 fathoms more elevated than that of *A* of the gallery. *A*, *B*, *C* is a subterraneous work of which the air ought to be temperate, that is to say at 10 degrees (55° Fahr.); but the air of the atmosphere in winter is at zero (32° Fahr.), and even below it, that is to say, 10 degrees (55° F.) less dilated or expanded than that enclosed in the subterraneous works; I ought then to consider above the pit *C B* a column of all the height of the atmosphere, which would have the opening of the said pit for a base, and of which the degree of heat is equal to zero (32° Fahr.) as far as the horizontal line, *C D* more than the column *C B*, which is at 10 degrees (55 Fahr.). I consider further upon the point *A*, a column, likewise of all the height of the atmosphere, consequently equal to that which is over the pit *C B*, with the difference that its degree of heat is equal to zero (32° Fahr.) over its entire height, whilst the former has a part of the 10 fathoms (toises) *C B* at 10 degrees (55° Fahr.), then the column of the atmosphere which follows the line *D A*, is heavier than that which follows the line *C B*, because it contains much more air in the same volume; therefore as it presses upon the point *A*, it will oblige the air contained in the subterraneous works *A*, *B*, *C*, to pass out by the point *C*, which will establish the current of air in the mine.

If I consider that which actually occurs in summer, in supposing the air of the atmosphere at 20 (77° Fahr.) degrees of heat as far as *C D*, which is the horizontal line, but *C B* is only at 10 degrees (55° Fahr.) which constitutes a part of all the column of the height of the atmosphere, then that column upon *C B* is heavier than that on point *A*, since the latter is in all its height at 20 degrees (77° Fahr.) of heat, whilst the former has a portion of the 10 fathoms (toises) of air less dilated, and, consequently, more weighty; whence it results that during summer the column of air upon the pit *C B* ought, by its own weight, to force the interior air out by the opening *A*, and thus to produce the circulation in it.

I have remarked for a very long time, and have heard it said by all miners, that the air circulated with difficulty in the mines at the budding and at the fall of the leaf, that is to say, during spring and autumn; it even happens that some works are suspended at that time for want of air, the candles and lamps could not burn but with difficulty. I had sought, unsuccessfully, to know the cause of it; but the problem is actually solved when we know that in the spring and autumn the external air approaches more of a temperature to that which is inclosed in the mines, consequently it makes, thus to speak, an equilibrium.

One may readily perceive all the difficulty which the air has to establish for itself a current in these seasons, when it is sometimes above, sometimes below the 10 degrees (55° Fahr.), particularly in those works of considerable extent, where the air has some distance to travel. As the degree of heat varies many times in the same day, the columns of air of the atmosphere press alternately upon the different openings of the mines, which renders the circulation in them very difficult.

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[1] *Ouvrage-en montant* or *echellon montant*, is an irregular excavation, which is made from below upwards, in following the stratum to extract the mineral.

Appendix G.

Memoir of M. Jars.

There is a practice in many mines, when the air fails, to lower into them grates of fire: that method is very good, and ought certainly to be had recourse to in the spring and autumn in the works which have been finished, according to the principles which I am about to establish; for if all the openings of a mine were made at the same horizontal height, the fire that they would lower to the bottom of the mine would extinguish itself there, as well as all the lamps and candles, unless the grates of fire were suspended at one-third part, or at the middle of one of the pits; it would produce, then, the effect of the furnace described by the translator of Lehmann, on the Art of the Mines, page 50, plate 3.

I have seen this furnace employed with success in a lead mine in the neighbourhood of Freyberg, in Saxony.

This refers itself always to that which has been said above, which is, to have the air more dilated in one place than another.

I will give below the least expensive means to procure a supply of air in the principal cases that present themselves in the working of mines.

Many persons are persuaded that it is only by greatly multiplying shafts to mines that they are able to introduce air into them. This is a dangerous error in a viewer who is at the head of a mining operation.[m] They ought to know that were they to make even ten shafts upon the same subterraneous work, if their mouths are at the same horizontal height, they will not have much more air than if they had but one, because then all the columns of air of the atmosphere being of equal weight with each other, it is impossible that they will be able to establish a current amongst themselves.[n]

This multiplicity of openings is very expensive, especially if the works are very deep; besides the more openings in a mountain are made, the more the filtrations of water are augmented, and consequently the expense of the operations. It is the same for horizontal works.

Here is an example that I have been witness to:—Having made a gallery which was 20 fathoms (toises) long from its mouth; they dug upon the stratum a pit about 10 or 12 fathoms; the air then failed them. It was advised to make a second gallery on the same level as the first, and which ended in the same pit, expecting by that to establish a current of air; but when it was finished they had no more air than at first. It was now determined to make an outer pit, which would lead into the subterraneous pit; it was then that they had in it air sufficient to continue the projected works. This fact which I have just stated happened in France.

Here is another of much greater consequence that I have seen in the mines of Schemithz, in Hungary, in the year 1758:—They continued the works of a gallery for draining, which, when completed, would be 2359 toises (2555 fathoms) in length; they had not more than 782 toises to make to finish it. As they worked in it from both sides, they hoped that the boring would be brought to a close in seven years. So that, according to every appearance, this gallery would be finished in the next year.

As the mountain is of prodigious height, it was impossible to make many pits of respiration. They had made for it one only in a valley. When it was at the depth where the gallery ought to be, they put workmen both on the right and left to accelerate the work. Then, as soon as they had made the opening with the part of the gallery which came from the side of the entrance, and that which was directed from the side of the mountain was a little advanced, they introduced into it some air by the assistance of a machine, a little resembling that of which I have had the honour to read the description to the Royal Academy of Sciences, and which serves to raise the water in the same mines. They would be able to substitute for it a pair of bellows, *a trompe*, which would have the same effect, and which would not cost the twentieth part of the expense of that machine; but they would have the power to pass it from one to the other, as we shall see afterwards.

Independently of that machine, they thought to commence, from the pit of the valley, a gallery parallel and on the same level as the great one, with the intention of making drifts from distance to distance, with the principal gallery to communicate the air to it; which they have used, and continued in all probability to do. It is, in the meantime, an expense, that every calculation makes more than 200,000 livres (£8,300), and which is very useless, as I shall prove.

If we notice that these galleries are at the same level, it is easy to conclude that the columns of air are at equilibrium amongst them, consequently the air is not able to change itself; but in order that it may be able to effect this, there is a door constructed, which separates the communication of the mouth of the second gallery with the pit of the valley; by that mode the air enters in winter by a second gallery, passes into the grand one, and proceeds to issue out by the pit. The contrary happens in summer. This second gallery represents simply a pipe or conduit, which could be prolonged to the same extent that the gallery might be advanced. This they would be able to do into the last principal gallery, by giving to it a sufficient capacity for the passage of the required air. That was very easy, since that gallery is 9 feet high by 5 feet broad, at the lowest part.

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[m] The dangerous error is in M. Jar's view. It is now nearly universally admitted as an almost mining axiom, supported by greater experience and more advanced science, that the more numerous and larger the openings to the day, the safer and better for the men and the mine, which has been shown on a previous occasion.

[n] This, of course, only applies to a system of natural ventilation, where the equipoise is affected by natural causes, as the rarefaction of the atmosphere by the summer's sun, the air of the mine retaining the medium, and more moderate temperature of spring and autumn; or the condensed air of the atmosphere in winter, from the abnegation of the sun's heat, leaving the air of the mine warmed by the temperature of the earth at a much higher degree, and having an unequal column of air over each pit, but if the pits are equal in altitude, then altered by a chimney over one or more, as in the case stated by M. Triewald, whose observation appears to be more correct than the reasoning of M. Jars. But these principles do not apply where the equipoise is disturbed by the rarefaction of artificial heat or the force of powerful machinery, when the air cannot have too many, or too capacious pits and passages for the facility of its ingress and egress.

There are also some persons who think that they cannot have the air in a gallery commenced from the day, unless that they have a pit of respiration every 50 fathoms (toises). The multiplicity of those pits is useful only so much as it is wished to accelerate the work of that gallery, by working in many places at the same time, which, however, is only practicable when the mountain is not too high, and the sinking is neither too deep nor too costly.

There has been communicated to me the translation of a memoir of M. Triewald, inserted amongst those of the Academy of Sweden, in the year 1740, page 444, in which he says:—"That he has observed in all the mines which he has seen, that the air descends by the pit the most profound or deep, and that it re-ascends by that which is less so; that truth (says he) is the same as the experiment of water in a bent syphon with two unequal feet."

To demonstrate it, he gives for example Fig. ii.

"Let us suppose (says he) a pit *A D*, of the depth of 35 fathoms (brasse), and the other *B C* of the depth of 45. It is incontestable (says M. Triewald) that the column of air *B C* will be heavier than that of *A. D* Now as the lightest will not counterbalance the heaviest, it follows that in yielding to the latter there is effected a continual change of air, so that the communication *C D* once established, the air will always circulate from *B* to *C*, from *C* to *D*, and from *D* to *A*."

I cannot persuade myself that M. Triewald has himself observed the example that I have ust given; for if I consider the mouths *A* and *B* of the pits, *A D*, *B C*, which I suppose at the same level, I say that the columns of air of the atmosphere which press on the point A and the point B, are in equilibrium, since they are of the same height, and have the same degree of heat; neither one nor the other are able then to force the air contained within the subterraneous passage or work *B C D A* to pass out of it, because it is itself in equilibrium. [o] But it is probable that M. Triewald has made his observations in a mine when there was an erection over the mouth of one of the pits; this erection changes the density of air of the columns, and is easily able to destroy the equilibrium.

He was, without doubt, persuaded that the air took the same route in all seasons. The artificial circulation of which he speaks in the same memoir, will be found comprised in the examples which I will give upon the application that may be made of the principles that I have just established.

A gallery is commenced at at point *A*, Fig. iii., directed under a mountain. I say that that gallery may be continued without making a pit of respiration, until the pillar *FI* of the gallery *A B*, which is above the horizontal line *A G*, be made equal to the height *K L* of the gallery; or rather, that the point *F*, forming the ground of the gallery at its extremity, would be at the same level as the point *K*, which is highest at its mouth. For this object I divide the gallery into two parts by a flooring E M, impervious in all its length, that the air may have no passage through it. This flooring, which the Germans call *treppenwerck*, is necessary to enable the wheel-barrow to travel over, and is not incommoded by the water which passes by the canal or conduit made upon the *thill* of the gallery. It requires, in this case, to be constructed with more care than when it does not serve such a purpose. It is constructed as the gallery is advanced.

By the aid of that partition there are two columns of air, of which the weight is different, because they are unequal in height and density; for example, the air in winter will enter the gallery by the canal *A E*, and will renew the air to the point *E*, proceeding to pass out by the mouth *M* of the gallery: the contrary will take place during summer.

Upon this principle, one is able to calculate of what length a gallery may be made without a pit of respiration. For instance, let us suppose the gallery *K L* of 6 feet, and which it is wished to give 18 inches declivity in the 100 fathoms (toises), it is evident that it would be but 400 fathoms, when the floor of the gallery at its mouth would be at the same level as the superior part at its extremity; that then the columns of air would be in equilibrium, and there would be no more circulation in it. This is good in theory, but I strongly doubt that it holds good in practice to that point. The reasons will be perceived sufficiently without there being a necessity for detailing them. But there is a remedy, which is not expensive: it is to make the pit *C D*, and to put a door at the place *N* of the gallery; for then, by a simple inspection of the figure, it may be seen that it will make a difference in the weight of the column of air of the whole height of the pit. If the mountain is not very high, this pit would be at least as useful to facilitate the extraction of the mineral, as for the circulation of air; but if on the contrary the mountain be very high, and that, the calculation made, the expense of the shaft would not compensate by the advantages which would result from it, in extracting the mineral, it will suffice to establish the current of air to make the pit *O Q* and the door *P* near to the mouth of the gallery. For, the little that this pit has of depth, one may see that it will be easy to push the gallery far into the mountain.

[o] M. Jars does not seem aware of the fact that the deepest pit of M. Triewald would have its air rarified by nearly one degree of temperature more than the shallow pit, disturbing the equilibrium and setting the air in motion. There is an increase of temperature in some of the deep mines of Britain from the surface of more than 25 degrees.

It may be also stated, in support of M. Triewald's observation, that the gallery communicating between his two pits would, as well as 10 fathoms of the deepest pit, have its air rarified, and, consequently, would produce a circulation by disturbing the equilibrium of the columns.

Appendix G.

Memoir of M. Jars.

But in case the air should still fail in a long continuation of the said gallery, they would be able to increase the height of the pit in constructing upon the point *O*, a chimney of so much greater height as the gallery may be prolonged inwards.

If in the same gallery *A B*, it is wished to deepen the pit *R S*, it will be easy to introduce the air into it, by putting a pipe or tunnel into the inferior canal of the gallery. It is necessary that it be quite tight, to prevent the passage of air, which will be carried to the extent that they will sink the shaft as I have represented it by *R T*. At the view alone of the figure, every one will be able to observe the demonstration.

I suppose the pit *C D*, figure 4, in a flat country, from the point *D*, they push the gallery *D F*; arrived at the point *F* the air fails in a manner to prevent the continuance of that work.

I will state, in the following example, what I think ought then to be done. But the course which is ordinarily taken is to sink the pit *E F* upon the point *F*; it is not doubted but that they then have a little air for the same reason that they have it by the pit *C D* at the point *D*, and in the gallery *D F* (we know that in a perpendicular pit they have the air to a certain depth, but which cannot be determined); but there is not a sufficient renewal of air procured by the pit *E F*, because the two mouths *C E* of the two pits are upon the same horizontal line *A B*; consequently the columns of air make an equilibrium between themselves. The gallery *F H* is continued; the air fails again when they reach the point *H*, in this case there are places where they make use of a chimney *E G* upon the mouth *E* of the pit *E F*; there is no doubt but by that they render the weight of the columns of air unequal, and by it establish the circulation. Those who are unacquainted with such chimnies, make a new pit upon the point *H*. With the aid of the chimney they are able to continue the gallery *F H* for a certain distance; but we may render it very considerable by pursuing what follows. I would make a flooring *K L* upon the gallery *F H*, similar to that of the first example; I would continue this ceiling with the gallery, and would make a door at the point *I*; for then I oblige the air which would enter by the mouth *C* to pass at the point *H*, that it may escape by *G*; the same that would enter by *G* would be obliged always in passing to the point *H* to go out by *C*. In following the same plan, I would sink a shaft at the point *H*, or in another place, and to such a depth as would be necessary, without other aid than that of a pipe or tunnel *L M*, which I will conduct to the extent that I shall deepen the pit, which pipe ought to have no communication but only with the canal which occupies the bottom of the gallery *F H*.

I ought to observe that it is not necessary that the chimney be made in a truncated cone; it would be even an inconvenience if the opening in it was too small; this would be easily perceived in summer when the air is obliged to enter into the mine by the said opening.

I suppose a pit *A B*, Fig. v., at the bottom of which I am obliged to make the gallery *B C* to follow the seam; *B* is the place where the the air has begun to fail; to renew it I construct the furnace *E*, described by the translator of Lehmann, at the side of the mouth of the pit, with a chimney, *E F*, which is raised as much as it is wished to procure more air; I place a tunnel or canal well closed all along one of the angles of the pit, which by one of its extremities *G*, enters the furnace; the other extremity of the tunnel is carried to the extent that the works advance, as from *G* to *H*, and from *H* to *I*.

One will easily conceive that in winter and summer there will be a natural circulation of air; but in the spring and autumn it will be necessary to make a fire in the furnace *E*, by the aid of which the air will be dilated from *E* to *F*, which will render the column lighter; then that which is upon the point *A* will press strongly from *A* to *B* to enter into the canal *I H G*, and will thus procure a renewal of air at the extremity *C* of the gallery. If it is wished to follow the *seam* on the other side of the pit, as from *B* to *D*, it will be easy to make another tunnel from *K* to *H*, which will divide the current of air into two branches; it would be necessary, then, that the tunnel *G H* be a little larger than when the air had to circulate in a single gallery.

After all the examples which I have given to procure a good and sufficient change of air in mines, it only remains for me to state, that in works rather extensive, it is often sufficient to know where to place doors properly in certain places to procure a good circulation of air. Sometimes they are even necessary also to hinder too great a current, which would extinguish the candles and lamps. Every person who will make himself master of all that has been said above, will easily find means in all cases that present themselves.

ERRATUM.

Report.—Page 11, line 8, for "blueness," read "redness."

Gurney's High Pressure Apparatus
for the
VENTILATION OF MINES.

Mitchell's Lithog. Newcastle

Vertical Section of Upcast Shaft.

FIG. 1.

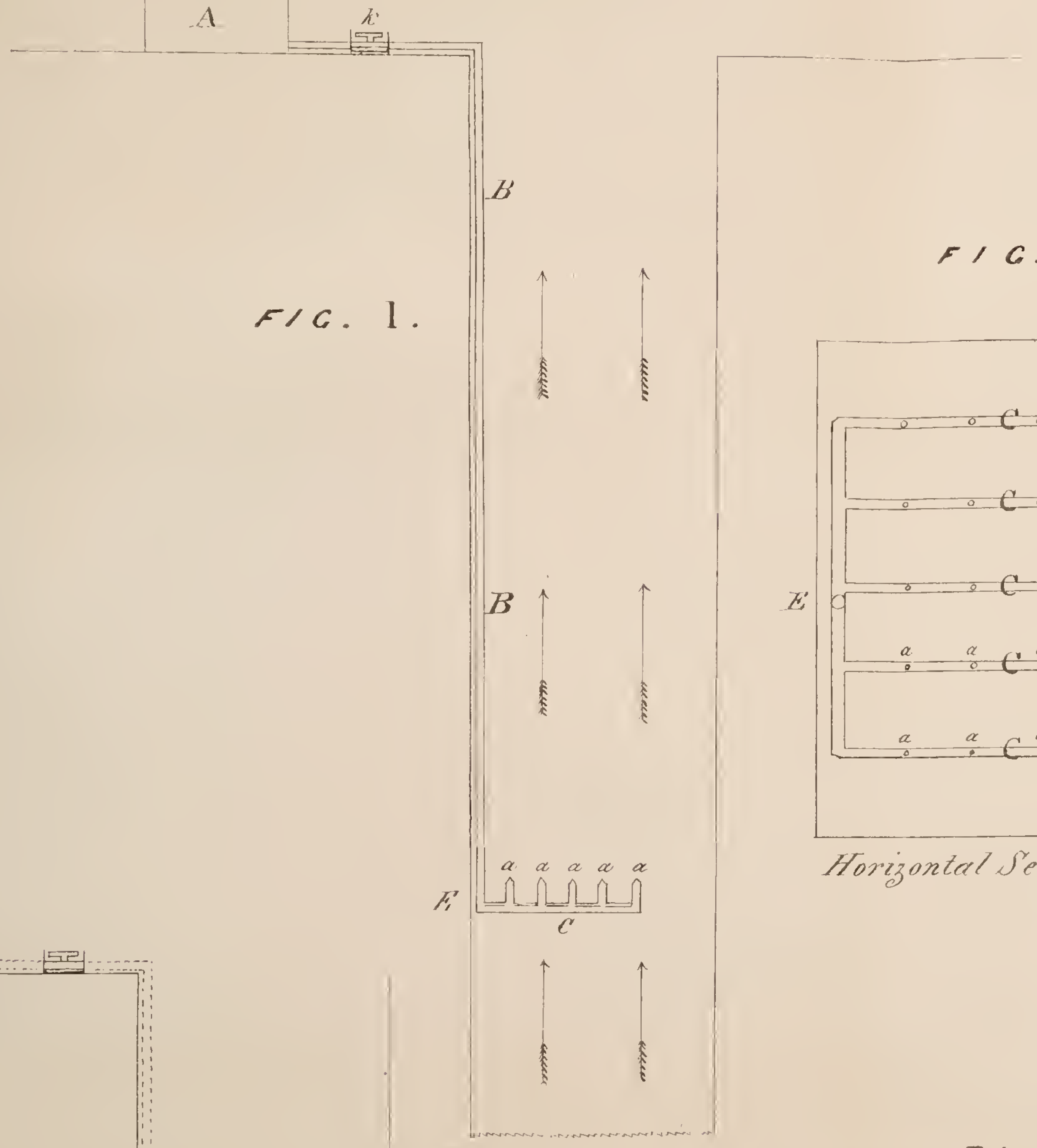
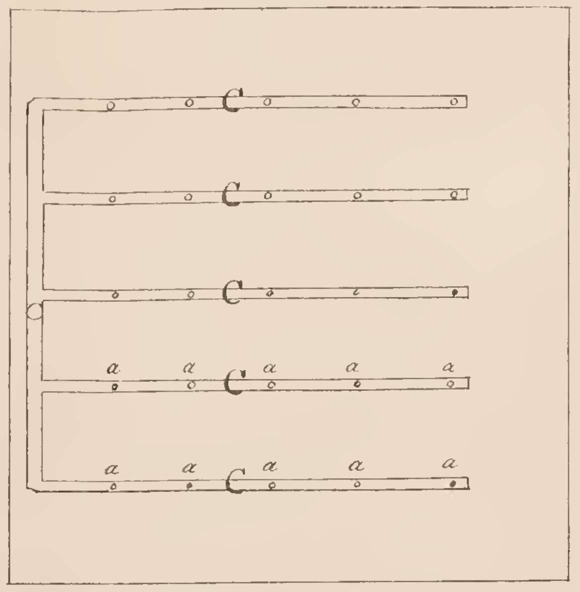
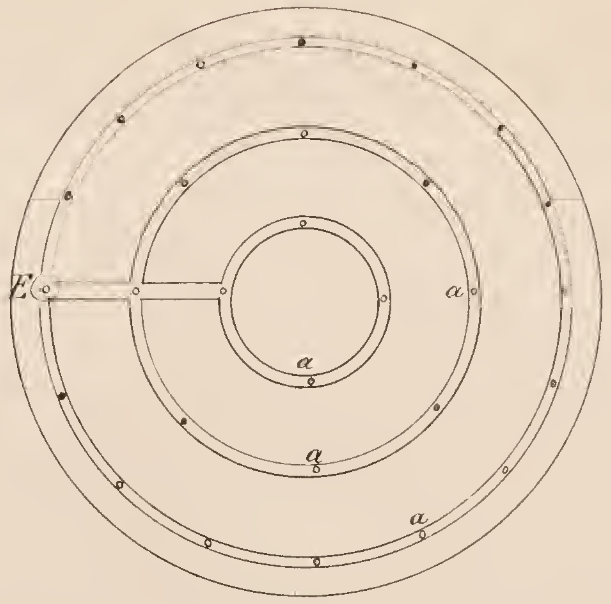


FIG. 2.



Horizontal Section at E.

FIG. 3.



Full size Drawing of Branch Pipe and Jet.

FIG. 4.

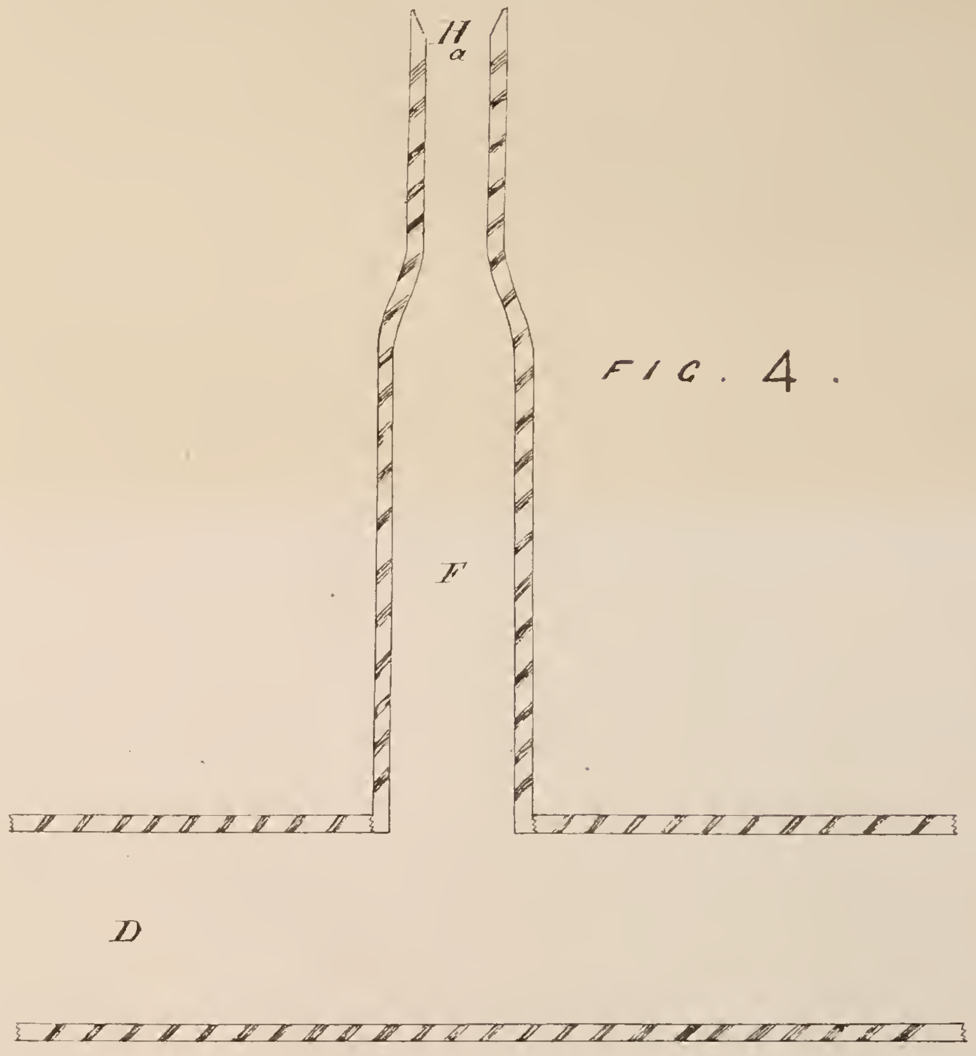


FIG. 5.

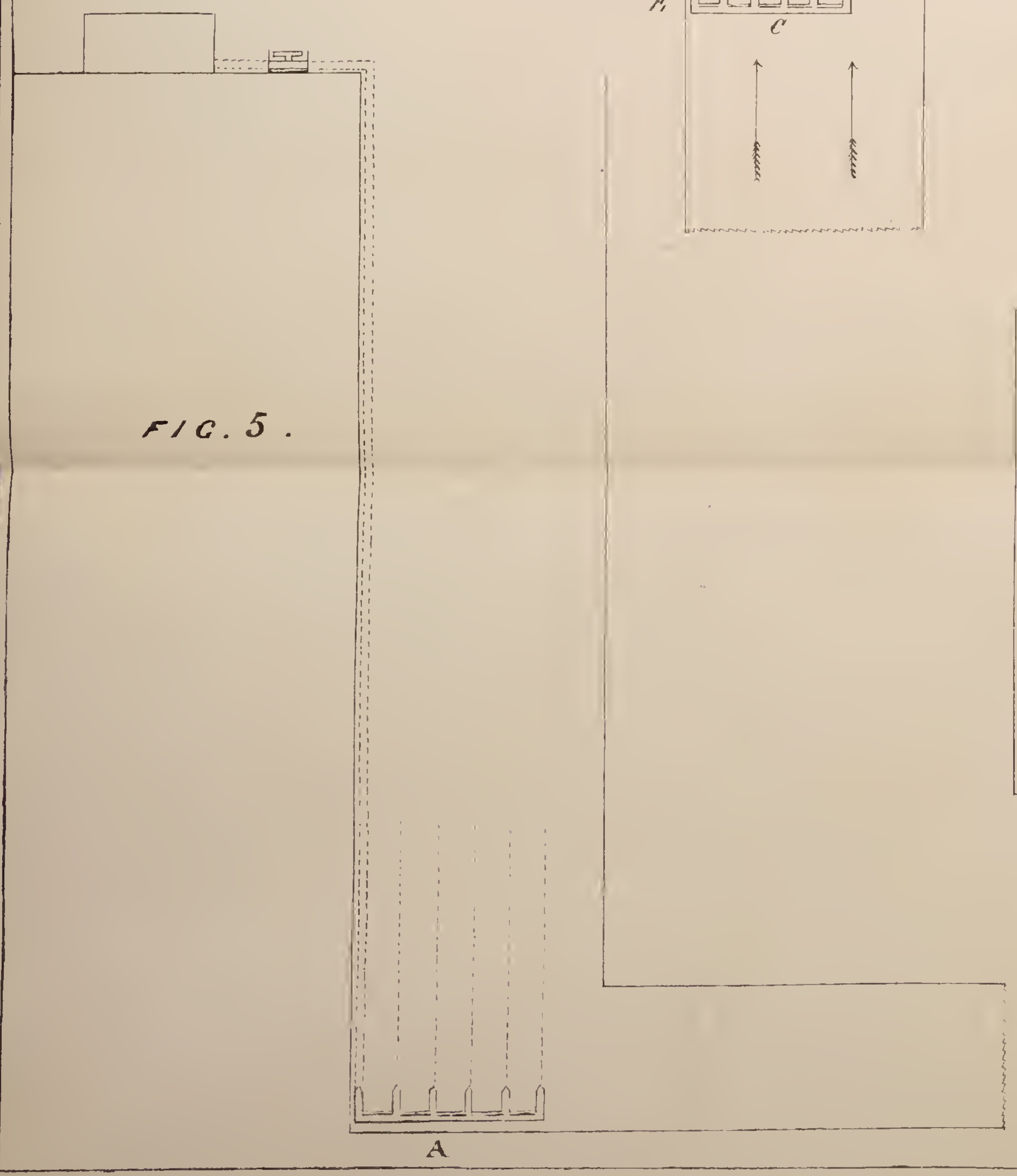


FIG. 6.

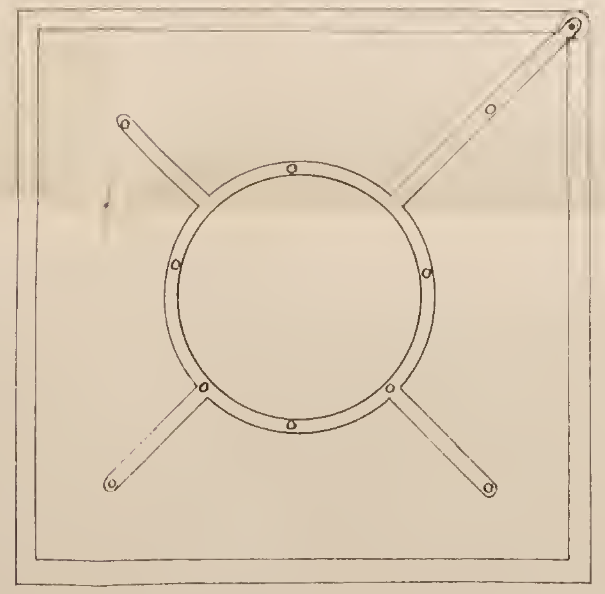


FIG. 7.

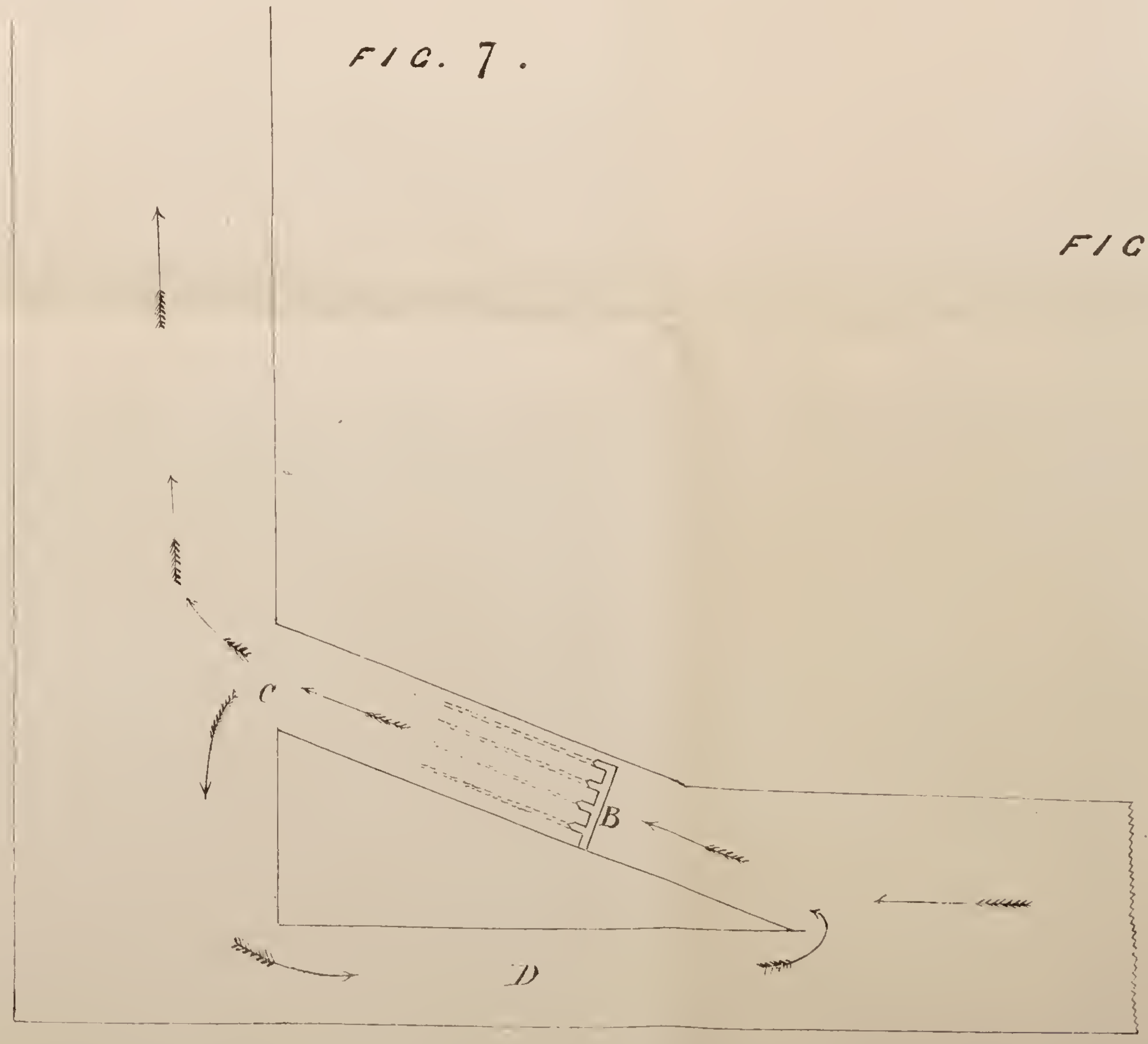
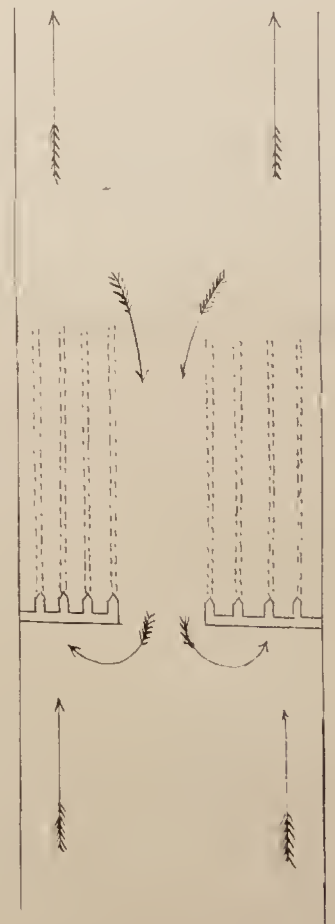


FIG. 8.



Appendix.

FIG. I.

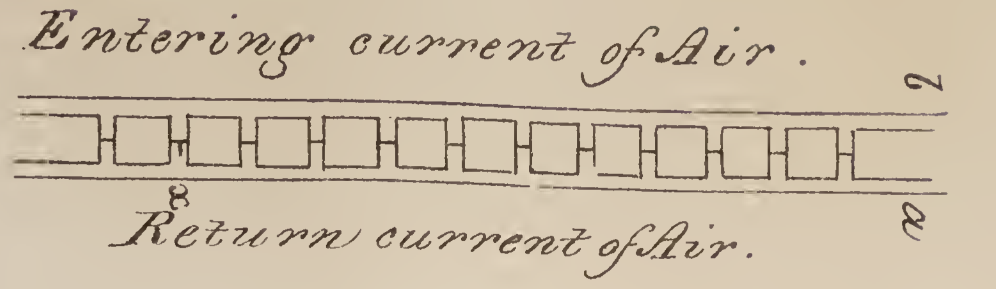


FIG. II.

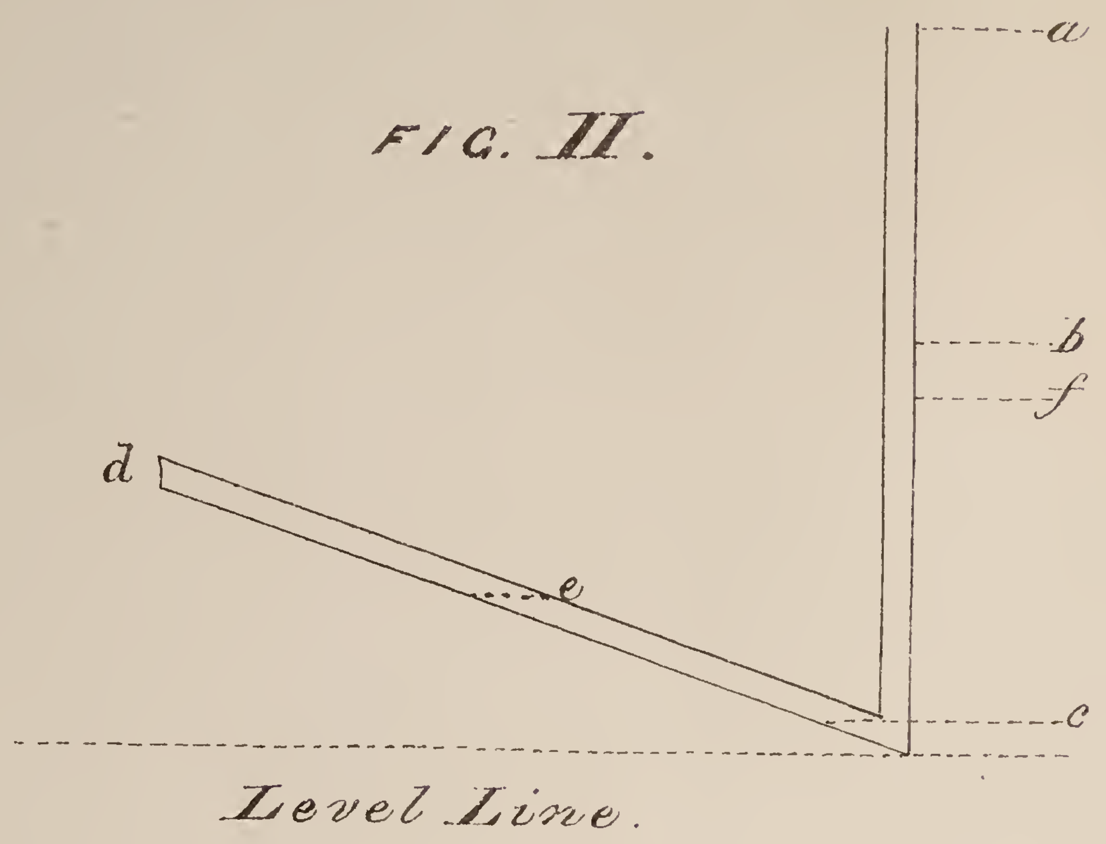
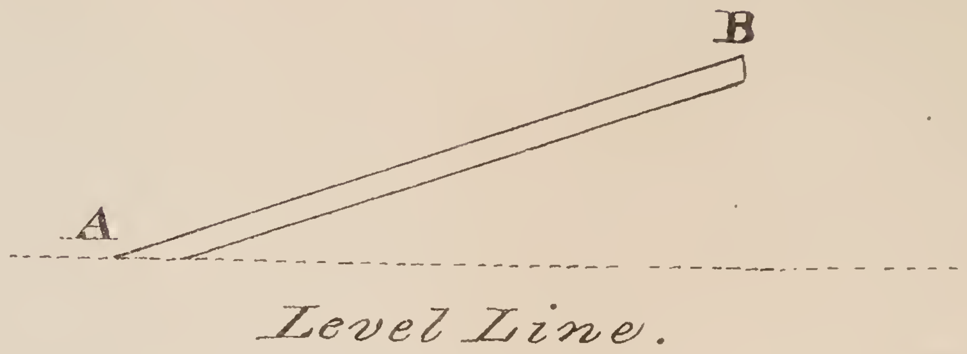


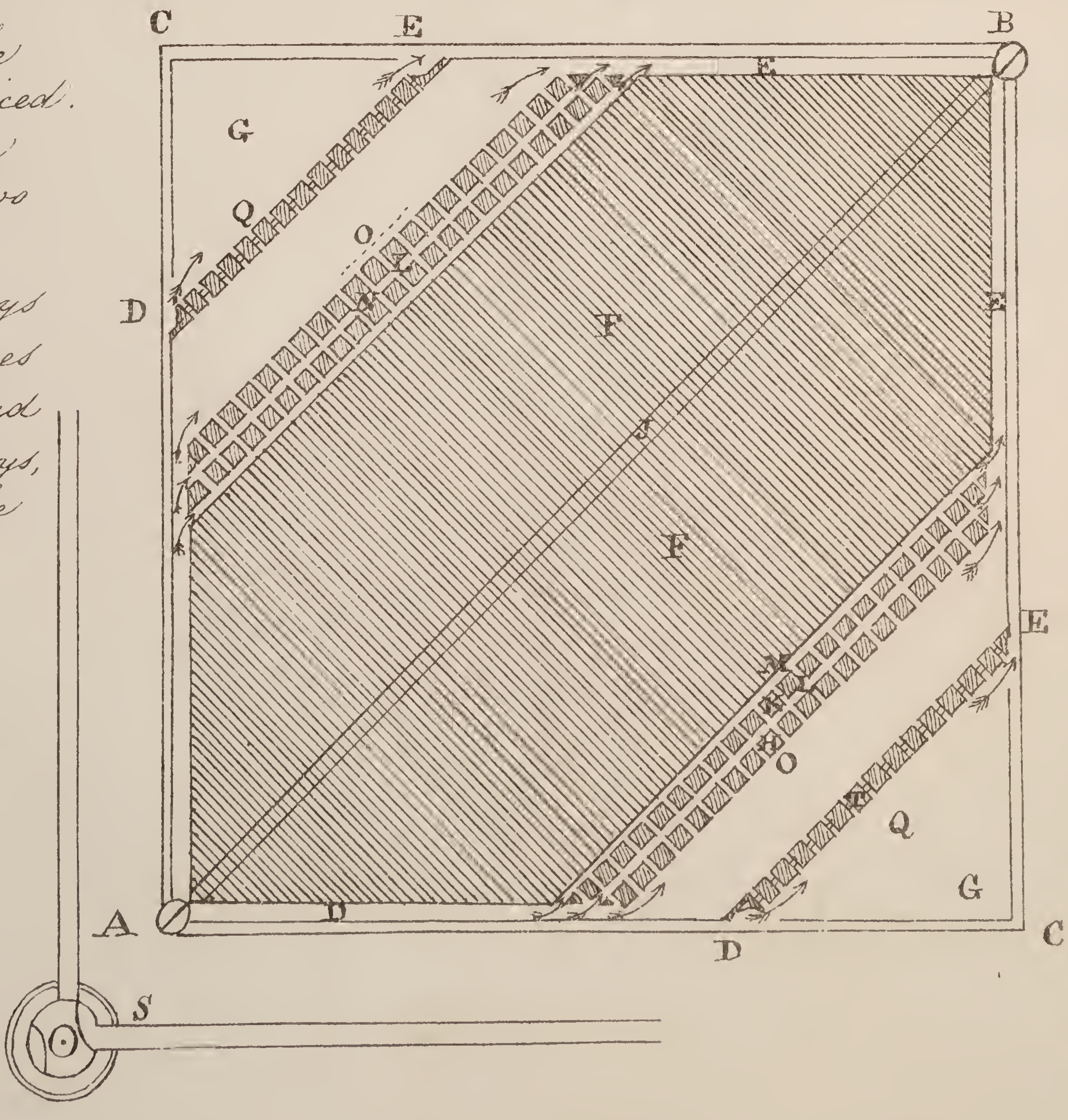
FIG. III.



Plan, of John Martin, Esqr., London.

FOR WORKING AND VENTILATING COAL MINES.

FIG. IV.



A. The Downshaft } To be
B. The Upshaft – } bratticed.
C. The Angles where the Headways from the two Shafts meet :
D. The downcast headways with ventilating Passages running by the Sides and parallel with the headways, which passages serve the purposes of ventilating the headways during their formation and more particularly that of ventilating the Goaf behind the Works.
E. The Upcast headway, similar in principle to the downcast D.
F. The field of unworked Coal.
G. The Angle where the Mining commences after the headways are formed. K. new pillars. J. a line of Coal which should be left at the Completion of the Works ~
H. Pillars of Coal in a line to protect the tramway and should not be worked out till a new & similar line of Pillars is nearly finished.
L. The existing tramway.
M. The new tramway in a state of formation.
N. Fixed lamps which light the tramway and other parts of the Works.
O. Dots representing wooden props to protect the Men working at the pillars K.
P. Angular reflectors which receive light from the lamps N, and reflect behind the works.
Q. The fallen roof after the whole of the Coal, has been worked away.
S. Regulating ventilator with tubes.
T. a line of Coal pillars with strong brick stoppings to seperate the Goaf from the Works.

Mitchells, Lithog. Newcastle

UT FOLDOU

APPENDIX (G.) TO THE REPORT ON ACCIDENTS IN COAL MINES.

PLATES ILLUSTRATIVE OF JARS' MEMOIR ON VENTILATION.

Fig. I.

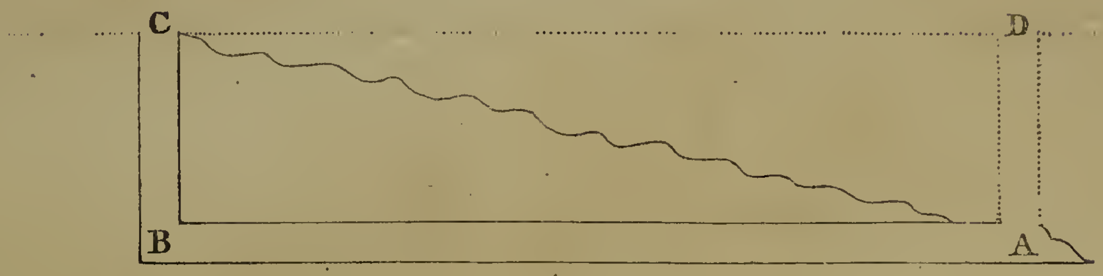


Fig. II.

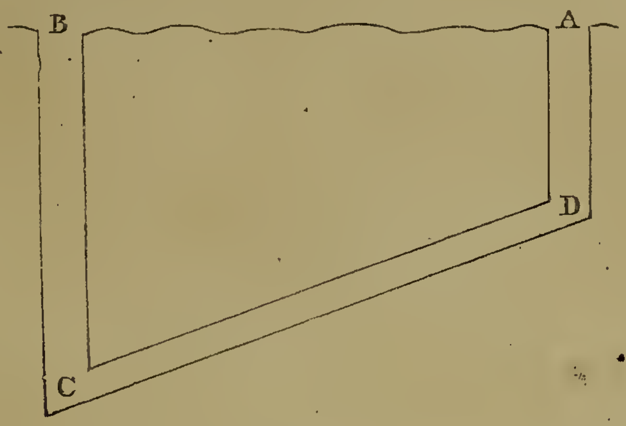


Fig. III.

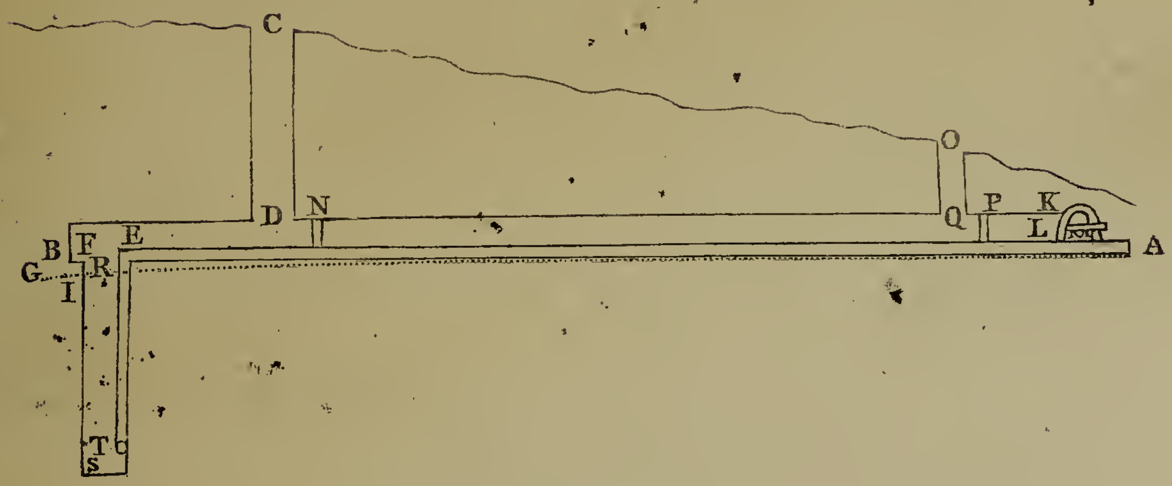


Fig. IV.

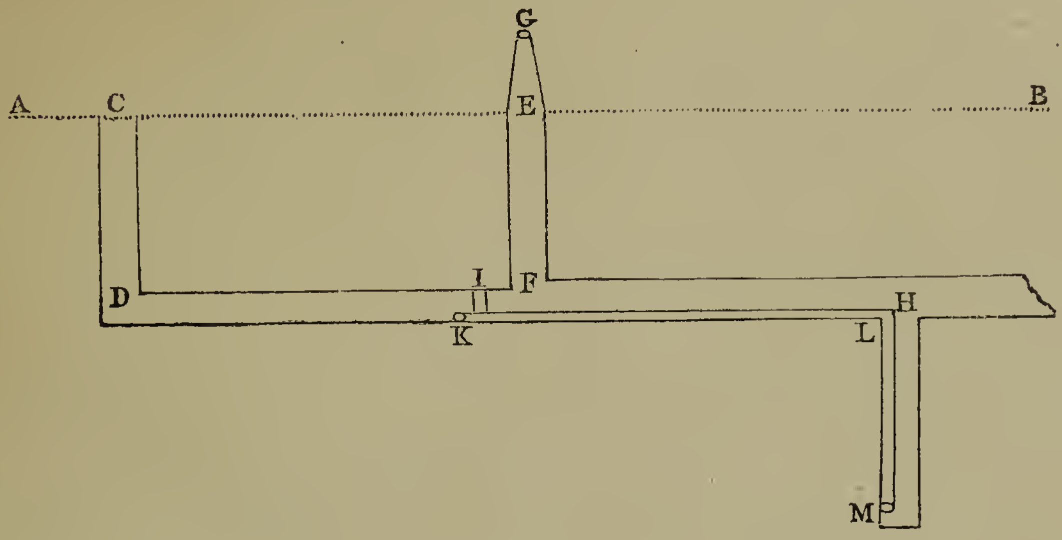
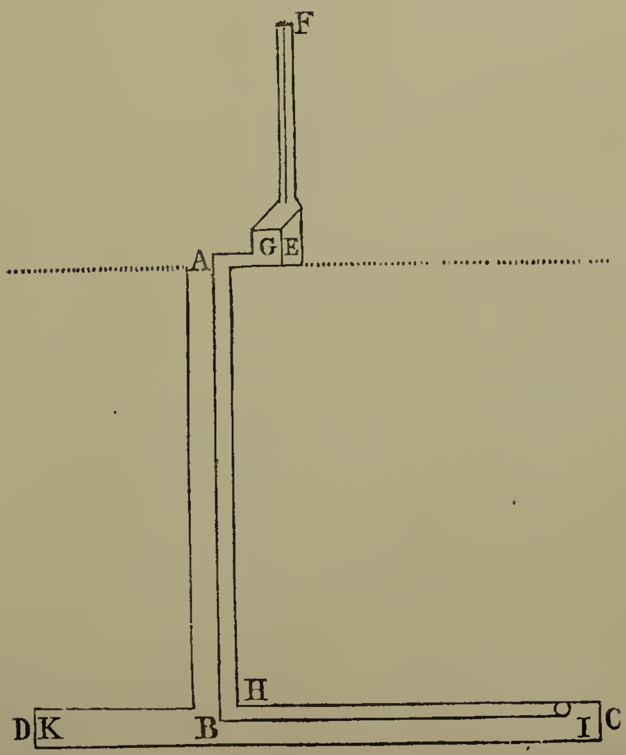


Fig. V.



THE REPORT

OF

THE SOUTH SHIELDS COMMITTEE

APPOINTED

TO INVESTIGATE THE CAUSES

OF

ACCIDENTS IN COAL MINES.

CONTAINING AN EXAMINATION OF—

SAFETY LAMPS;
VENTILATION;
SCIENTIFIC INSTRUMENTS;
INFANT LABOUR IN THE MINES;
PLANS AND SECTIONS;
SCIENTIFIC EDUCATION OF OFFICERS OF MINES;
GOVERNMENT INSPECTION; AND
MEDICAL TREATMENT AFTER EXPLOSION.

WITH PLANS AND APPENDIX.

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